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PASSIVE SOLAR RETROFIT

Prepared for
MONTANA DEPARTMENT of NATURAL RESOURCES and CONSERVATION



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PASSIVE SOLAR RETROFIT

Prepared by

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January, 1980

Prepared for

Montana Department of Natural Resources and Conservation
32 South Ewing, Helena, Montana 59620
Renewable Energy and Conservation Program
Grant Agreement Number 054-781

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1. FOREWORD

Although this report does contain all of the information required by the grant contract, the grantee is more than willing to supply additional information as requested. In the interests of technology transfer, (the real value and purpose of demonstration grants programs), the grantee is assembling a narrative 35mm slide show of this project's construction sequence (at his own expense), for submission to DNRC at a later date. This tool should prove to be effective in illuminating some of the successes (and failures) of this project for others contemplating similar projects. It should also be noted that the original proposal to DNRC for funding contains a wealth of design and background information not herein repeated; therefore, this report should be considered a companion document to the original proposal.

While the grantee is aware that this project's very uniqueness may require that some imagination be brought to bear on the process of translating the solarium's design parameters to other more conventional (residential) contexts, he also feels that the inherent simplicity of the basic physical principles involved in passive solar technology is such that, in the context of a demonstration, this project should be useful. If anything, this uniqueness should enhance the visibility of the demonstration.

2. ABSTRACT

This grant is for assistance in funding the construction of a 12' x 60' passive greenhouse attached to a unique concrete structure (in Butte, Montana) which is currently being renovated by the grantee. The primary purpose of the project is to provide (and demonstrate the concept of providing) solar residential space heat.

Glazing for the greenhouse or "solarium" will be "Exolite"... (formerly called Acrylite SDP), double-skinned acrylic sheet. This material, a relatively new product, performs approximately the same as double glazing in a solar context, yet weighs only one-fourth as much, and costs about one-half as much. Thermal storage for heat collected by the solarium has been accomplished by using the walls of the structure itself, an insulated floor of concrete and used brick pavers, and water in 55 gallon drums. Air warmed by the sun rises to the apex of the solarium, into a manifold from which a thermostat-activated fan ducts it into the residence. Make-up air is ducted from the coolest portions of the residence to the solarium. Summertime overheating will be prevented by "dumping" heat through vents located at the apex of the structure, the "kneewall", and at each end wall.

In the context of the project a unique method of vent operation has been developed using automotive "air-adjustable" shock absorbers as inexpensive hydraulic cylinders. A routine for programmable hand-held calculators, (such as Texas Instruments TI-59), has been developed for use in the otherwise tedious task of determining the mounting geometry of the shock absorbers.

The solarium is expected to provide a substantial proportion of the space heat required by both itself and the residence to which it will be attached; an aesthetically pleasing spatial addition to the residence; a

high proportion of the vegetable requirements of the occupant; and a highly visible demonstration of the concepts of passive solar technology as an alternative to non-renewable energy sources for space heating.

3. LIST OF EXHIBITS

<u>Exhibit No.</u>	<u>Title</u>	<u>Page No.</u>
1	Timber Butte Milling Co. Circa 1914	53
2	Project Site Circa 1978	54
3	Completing the Solarium/Greenhouse	55
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5. BACKGROUND STATEMENT

I am a Montana born and educated graduate architect currently involved in investigation of solar architecture with an emphasis of interest in "passive" solar design and technology. For the past several years, I have been modifying a large concrete ore bin structure in Butte, with the goal of transforming it into a place in which to live and experiment with solar technology. Because the structure I am dealing with is quite unique and somewhat unusual, a general description of it and its history is in order:

In the early days of Butte's colorful past, one of the famous "Copper Kings", Senator William Andrews Clark, built and operated a zinc mill here. The mill, known as the Timber Butte Milling Company Facility, was located on the slope of Timber Butte, a prominent topographical feature just south of the City Limits of Butte (see Location Map, Exhibit 5). The mill was located on the side of Timber Butte to take advantage of gravity flow in some of the ore processing techniques. (*) In the course of events, the Anaconda Company acquired the mill from Clark, and operated it sporadically until the Company dismantled the buildings in 1948. While perhaps 90 percent of the property was leveled, the large concrete "crude ore bins" proved to be built too substantially to be economically demolished. Anaconda sealed the bins, and the property remained vacant until I purchased it in 1972.

A photograph from the collection of C. Owen Smithers, an early Butte photographer, is attached as Exhibit 1. This photograph shows the entire property as it appeared circa 1914, with the ore bins, which are all that now remain, highlighted. Exhibit 2 depicts the structure as it appeared at the start of this project. Exhibits 3 and 4 show the building with the Greenhouse/Solarium completed. Exhibit 5 depicts building conditions in plan and section.

(*) Indicates that further information is available in the original project proposal.

6. OBJECTIVE

The basic premise of this project, both at the time of the original proposal was written and now, is that there is a need to further demonstrate solar heating techniques in Montana, especially passive systems. My experience indicates that the concept of "solar energy" as it applies to space heating that is held by the public in general most closely resembles the state-of-the-art active water system. Collectors, piping, pumps, and "rock box" storage units form a large part of the image most people visualize when thinking of "solar heating"...and more often than not, the "man on the street" feels woefully inadequate (perhaps properly so), to the task of properly designing, maintaining, and operating a system of such complexity and cost.

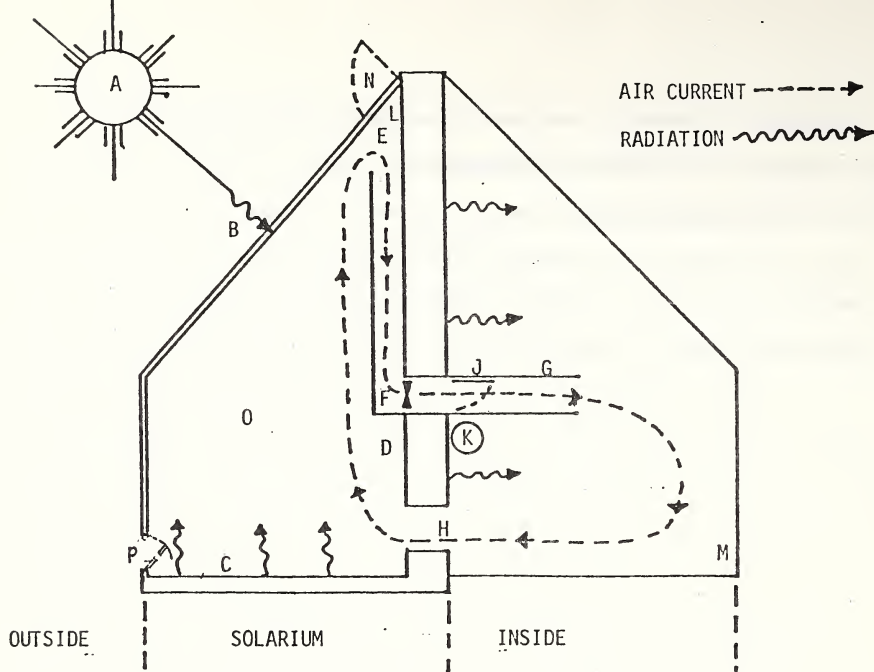
On the other hand, the basic concepts of passive solar heating (i.e., the "greenhouse" effect coupled with thermal storage), are much easier to understand, especially when demonstrated. Experiencing the warmth, as well as witnessing the relative simplicity with which it is produced in this project, can reasonably be expected to motivate people to start thinking about ways to incorporate an attached greenhouse on their own homes. The substitution of other thermal storage devices (i.e., water drums or masonry) for the concrete walls unique to this structure should be a fairly easy conceptual gap for most people to bridge.

In designing this project, I dealt with four main elements:

- (a) The solar greenhouse as a source of (space) heating;
- (b) Heat loss theory (with respect to massive structures);
- (c) The availability of solar radiation at a specific (localized) site;
- (d) The transfer of usable heat from point of collection and/or storage to point of use.

The reader is referred to the rather lengthy technical section of the original proposal for a detailed treatment of the design process as it related to these main elements.

Suffice it to say that the project was built with only minor changes as will be explained later. Figure 1 shows the operational schematic of the project as designed, and Exhibit 6 shows actual construction details.



SCHEMATIC SCENARIO

The Sun (A) shines through double glazing (b) onto the concrete and used brick floor (C) and concrete wall (D) of the Solarium. These surfaces are dark in color, and absorb heat rapidly. As they are warmed, so too is air in the Solarium. The warmed air rises to the apex (E) of the Solarium where it is collected, ducted horizontally to the center of the building and pulled down by a fan (F) into ductwork (G) which directs the warmed air into the residence. As this happens, cooler air is pulled from the residence through vents (H) in the concrete wall, and into the solarium for warming, thus completing the cycle. A damper (J) in the main duct can be closed at night to prevent reverse thermosyphoning.

The fan is controlled by a differential thermostat (K) which responds to temperature sensors (L and M) located at the apex of the Solarium and, at the coolest part of the residence respectively. Night time and sunless day heat storage takes place in the mass of the mass of the concrete wall and concrete floor of the Solarium. Overheating is prevented by opening vents (N) at the apex, and vents (O) at the endwalls, and intake vents (P) at the kneewall; thereby creating a natural convection current which exhausts heat.

OPERATIONAL SCHEMATIC OF PROJECT

FIGURE 1

7. PROJECT IMPLEMENTATION

The original proposal for this project was submitted to the Montana Department of Natural Resources and Conservation in February 1978. Notification of selection for grant funding was received on June 6, 1978, and the one-year contract period commenced on July 27, 1978. Construction continued smoothly and on schedule until November of that year, when one of the most inclement winters on record virtually stopped progress until May of 1979. Because of this seven-month hiatus the grantee applied for and received permission to extend the 12 month contract period by three (3) months to October 27, 1979. This final report is being submitted in January 1980, within the three (3) months after the end of the contract period which DNRC allows for preparation of the final report.

7A. PROJECT PLANNING AND EQUIPMENT ACQUISITION

Due in part to the very clear and informative "Guidelines for Preparation of Grant Proposals" published by DNRC, I was able to organize and present a thorough and very detailed proposal for the project. This proved to be an invaluable asset in planning and accomplishing the actual construction and acquisition of equipment because for the most part everything had been accounted for in the design phase. Having prepared detailed dimensioned construction drawings for the proposal, I was able to simply "start working." This is not to say there weren't problems and changes along the way, but in general my experience highlights the value of detailed drawings and thoughtful planning before commencing construction. In addition, the inherent simplicity of passive solar architecture significantly simplified the process of "equipment acquisition"...(buying the parts): There just aren't a lot of parts to buy, especially in comparison with an active solar system. Nonetheless, it is instructive to look at the major elements of the building and say a few words about some things to watch for while shopping and planning:

1. Excavation - About half the digging required for footings and foundation was accomplished by hand with a pick, shovel and wheelbarrow. After over 240 wheelbarrow loads were removed, I rented a Case Uni-Loader from the local equipment rental shop for \$12.50/hour and finished the excavation in less than five hours. One can become quite adept at operating these small machines with less than an hour's practice and they'll out do a shovel anytime!
2. Footings - It's worth it to spend time making sure you're off to a true, square, and level start with any building by forming the footings carefully.* Mistakes made "in the trenches" haunt you 'till the very end. All form work was done with lumber which was carefully cleaned and later used in the walls.

For smaller pours like this, I've found that it's much less hectic to mix your own concrete in a small, portable, (electric), mixer than to call up the local batch plant. The cost is about the same, even less if you pay delivery charges by the mile or pay special charges for small quantities.

3. Foundation - Having carefully dimensioned drawings again paid off in figuring quantities and "coursing" for concrete block. I used lintel or bond beam block (which has special "knock out" ends for the top course of the foundation wall. This enabled me to install steel reinforcing bar horizontally in grout to achieve a "bond beam" which ties the wall together and provides a stronger point of attachment for the wooden structure to follow. Anchor bolts were set in the wet grout of the top course to allow bolting the structure firmly to the foundation.

* For levelling over long distances, a water level makes an inexpensive substitute for a transit. I made my own with \$10 worth of flexible, clear, plastic tubing: Fill the tubing with water, work out the air bubbles, and when the ends are held verticle, the water level in each end will be the same. You can then check from a reference point to anywhere within reach of your tubing length. (Slip a stopper on the ends when you aren't using it.)

I insulated the exterior of the foundation with two inch rigid DOW Styrofoam. (This product is blue in color and has a low water permeability to make it suitable for below-grade application.) The theory here is that by placing the insulation on the exterior, you can get "credit" for more thermal mass (the foundation) in the greenhouse.

Note:

Unless you're building a relatively small greenhouse where every square foot of floor space counts, I would think twice about exterior insulation on the foundation. The problem is that the rigid insulation degrades in the ultraviolet light of the sun, provides a home for burrowing rodents, and is subject to mechanical damage. To protect the insulation one must therefore apply a more durable finish on the exterior surface of the insulation. The common solution, and the one I used, is to apply a sheathing of cement-asbestos board, which is expensive, difficult to work with (requires drilling all nail holes and "eats up" saw blades), and dangerous...wear a mask when cutting it! DOW suggests alternatives such as pressure treated wood, stucco, rigid vinyl sheet, aluminum coil stock, and some vinyl-acrylic coatings.

I offer the alternative of insulating the foundation wall on the inside where the job of protecting the rigid insulation, although it still must be done, is easier because you aren't dealing with as harsh, corrosive, and moisture-laden an environment. The loss of thermal storage contributed to the greenhouse by the masonry or concrete foundation wall can be made up by adding a relatively small amount of water in containers sitting directly in the sun in the greenhouse. In my case, I figured the thermal mass contributed by the south wall foundation could have been

replaced by about three 55 gallon drums of water in the greenhouse space. The thing to remember is that water has the advantage over masonry for the same heat storage capacity of about 5 to 1 on weight and about 2 to 1 in volume. If sacrificing some floor space to a drum or two of water gets you out of ticklish problem protecting exterior insulation on your greenhouse, it may be worth it; (I paid more for the cement-asbestos board than three drums and some protection for interior insulation would have cost).

4. Framing - The value of dimensioned drawings was again highlighted in the process of framing the greenhouse. In my case the basic module was the 4' 0" centering required for the type of glazing being used, and extra care was taken to achieve as accurate a framing job as possible because the glazing is machine-made to exacting tolerances. Special attention was given to selecting lumber for the rafters which was as straight, sound, and knot-free as possible. I found it worthwhile to pre-paint all of the exposed structural framing with both primer and finish coats before the framing was started. This ensures a good paint job for protecting the wood, and eliminates both masking and painting from a ladder or scaffolding.

Speaking of scaffolding, I found it worthwhile to spend some time (a day and a half) building my own, rather than renting commercial metal scaffolding. I used salvaged and scrap lumber, and avoided any rush to return rented scaffolding for which you pay by the day.

Note:

When working from scaffolding at 22 feet above the ground as I was, one should use extreme care and move slowly. In addition,

do everything you can on the ground, minimize work, and especially close tolerance work, from the scaffold. For instance, all of the rafters were pre-cut, pre-painted, and had plywood bearing plates on each end, making it easy to balance them in place and, after careful centering measurement, simply nail to headers through the bearing plates. This process allowed framing accuracy of less than one-quarter inch in sixty feet!

The end walls of the greenhouse were changed slightly from the original proposal for both thermal and aesthetic reasons. They were built twelve inches thick by using double two by four walls. This allowed the addition of twelve inches of fiberglass insulation (R-38), eliminated the thermal bridging effect of studs and plates,* and kept the walls in better visual scale to the size of the greenhouse addition and the large concrete residence. Additionally, the walls were covered on the exterior with plaster and painted to match the concrete color; thus achieving a better visual integration between the building and the greenhouse addition.

Note:

This was the first experience with plastering for me and my father. We found it really quite unmysterious after reading a few pages from "how-to" books and actually trying it. (We started at a place that didn't show, however.) We used metal lath, which goes on with blue nails, over building paper on plywood sheathing. Remember that metal lath has a top and bottom, and when installing it on vertical walls make sure the angle of the flattened wire points up, creating a myriad of tiny "shelves" to hold the plaster in against the wall. (If the "shelves" angle down, you have the lath upside down, and the plaster will tend to fall off.)

* We used plyclips at plywood edges to eliminate edge blocking, and tied the two walls together with internal bridging to eliminate most of the thermal conductivity. The inner and outer walls are tied together at the top slope with one-half inch plywood rather than dimensioned lumber plates.

5. Glazing - Because the Acrylite SDP used for glazing is a key element in the overall project, I've attached a wealth of technical information from the manufacturer. (See Appendix I.) Those wishing further information, either technical or regarding pricing and ordering are referred to Mr. John N. Harvey, Marketing Development Section, CY/RO Industries, Bound Brook, New Jersey 08005. Tele: (201) 356-2000, extension 2117. Note that as of this writing the manufacturer is changing the name of the product from "Acrylite SDP" to "EXOLITE".

At the time I purchased the material for this project it was being handled through the main office/factory only, and at \$2.00 per square foot. In the time since then a national distribution system has been created, (Mr. Harvey will send a list of over 60 dealers), and as with everything else the price has gone up. My most recent telephone calls reveal that Brother Sun of Sante Fe, New Mexico offers the material at the lowest price to the Intermountain Region (\$2.25 per square foot). Their address is Route 6, Box 10A, Sante Fe, New Mexico 87501. Tele: (505) 471-1535. Because prices can vary, I suggest contacting Mr. Harvey at CY/RO.

Note:

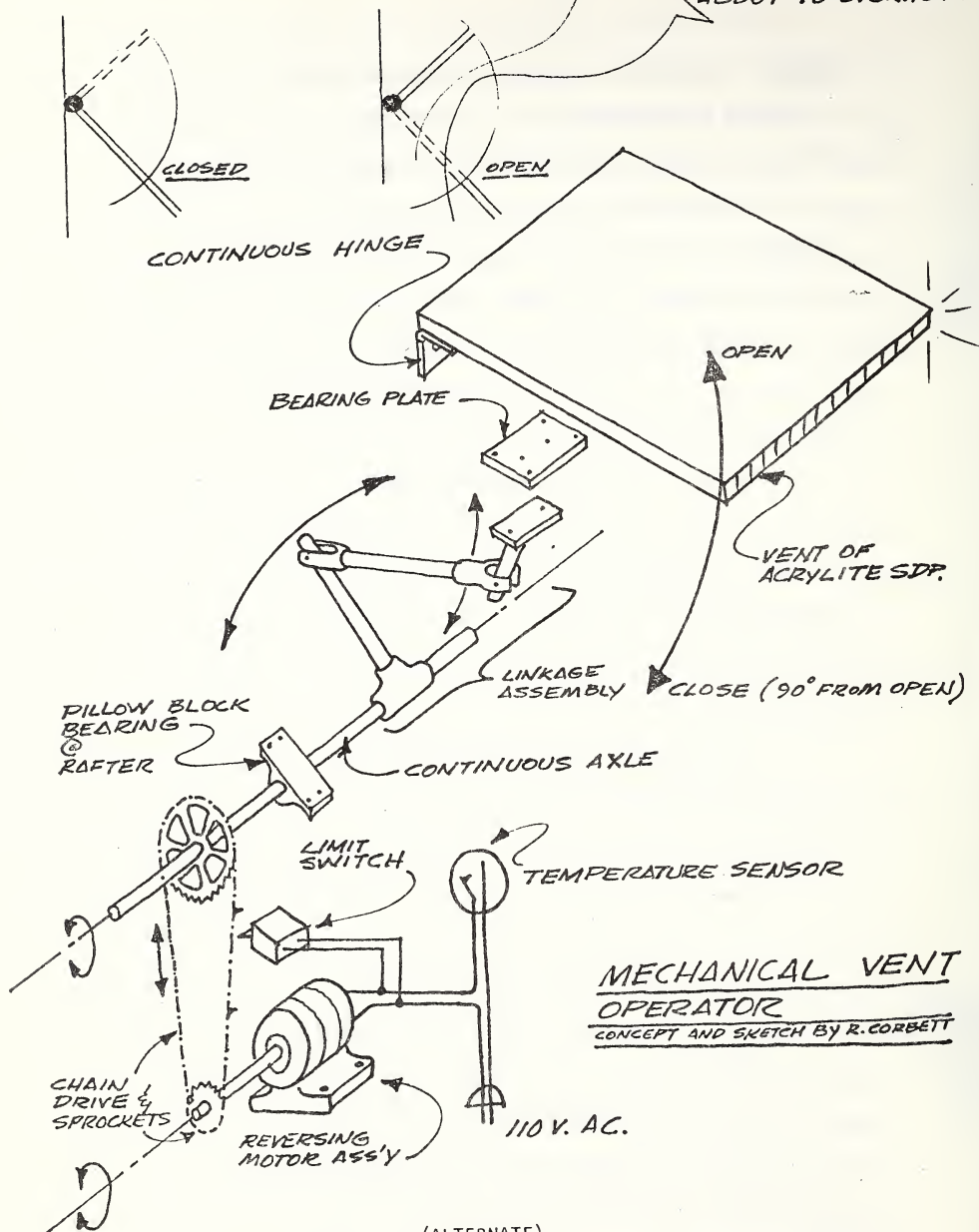
As is the case with all acrylics, this glazing material has a significantly large coefficient of expansion. This necessitates allowing for movement in the glazing with respect to the glazing bars which clamp it in place. Although the aluminum and PVC system provided by CY/RO and used in this project is designed to allow for expansion and contraction, one must be very careful when measuring sheets for cutting. Pay close attention to the manufacturer's instructions on this point.

6. Venting - As per the original proposal, two vent operator schemes were considered during the course of construction. The first, (see Figure 2) was a somewhat conventional, mechanical system operated by a reversing electric motor. This system, though it still has promise, was discarded in favor of a more elegant and somewhat unique air-hydraulic scheme. (See Figure 3.) The basic reason for not pursuing the electro-mechanical system was not an inherent flaw, but rather that the hydraulic system seemed to offer much less complexity and cost, as well as more reliability and ease of installation and maintenance.

As far as acquisition of materials goes, the venting mechanism presented no real problems. The vents themselves (which are glazed with the same double-skinned acrylic as the rest of the structure), were pre-built, including hinges and glazing as a 1 x 2 pine frame sitting on a 1 x 4 pine "box", which was rather easily attached to the structural rafters. (See Figures 4 and 5.)

The original concept for actuating the vent system called for utilization of city water line pressure to provide a driving force (via a diaphragm tank) to compress air. Subsequent investigation revealed that the cost of diaphragm tanks of suitable size are as expensive as a small air compressor/tank combination. In addition, a check of available water pressure revealed a general drop in line pressure during the hottest part of the summer to be the norm rather than the exception. Because water pressure would be lowest at the very time the system would demand the highest pressure; i.e., venting would be required, a small compressor (which, through the use of a quick-disconnect can perform other service as well), was substituted. This unit was purchased from Sears Roebuck and all other items came from local automotive, hardware or plumbing outlets. The air distribution system is one-fourth inch copper pipe and fittings. The actual air shocks are stock number 39106 Gabriel "Hi-Jackers" purchased

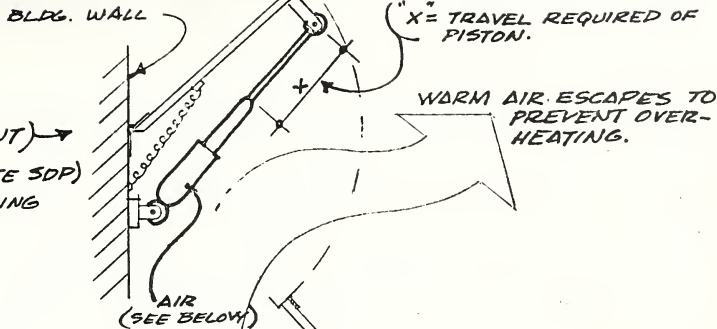
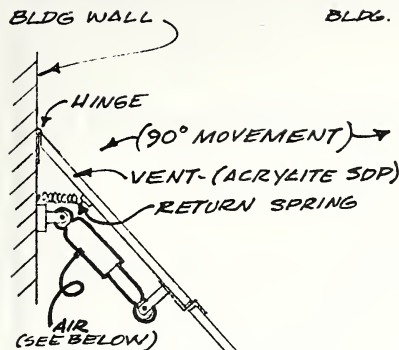
WARM AIR ESCAPES
WHEN SOLARIUM IS
ABOUT TO OVERHEAT.



MECHANICAL VENT
OPERATOR
CONCEPT AND SKETCH BY R. CORBETT

(ALTERNATE)
VENT OPERATOR SCHEME...
(FROM ORIGINAL PROPOSAL)

FIGURE 2



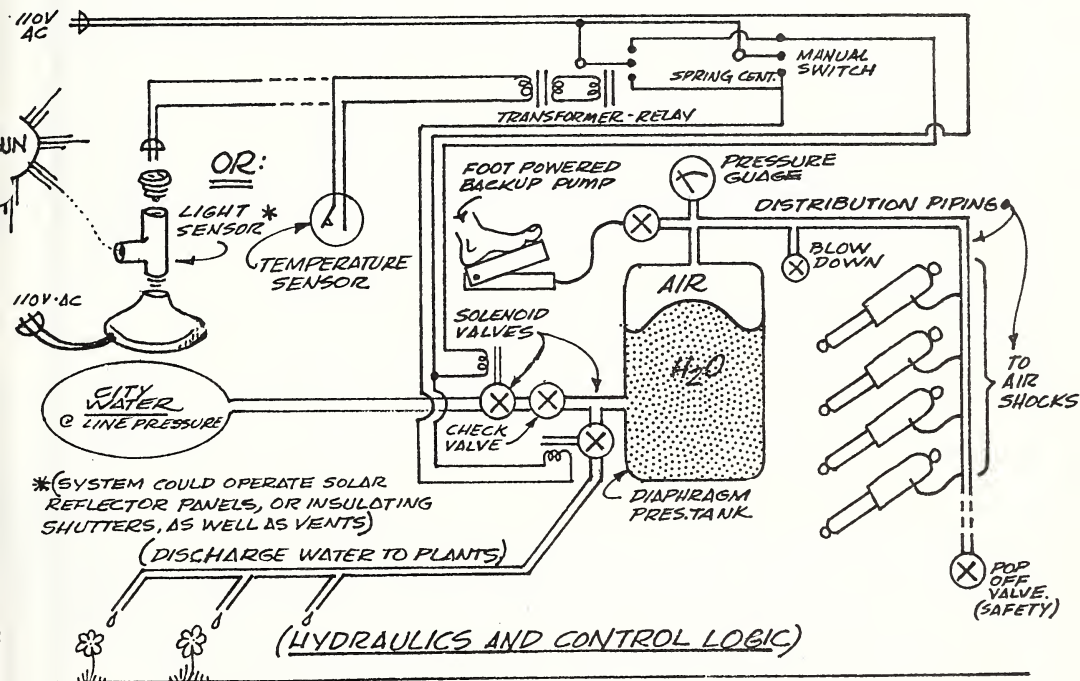
POSITION

- NO AIR PRESSURE
- "SHOCK" RETRACTED
- SPRING RELAXED.

(MECHANICAL LINKAGE)

OPEN POSITION:

- AIR PRESSURE IN LINE
- "SHOCK" EXTENDED
- SPRING UNDER TENSION



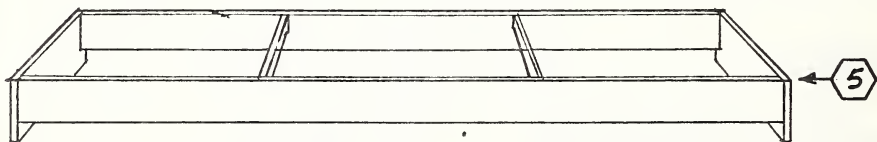
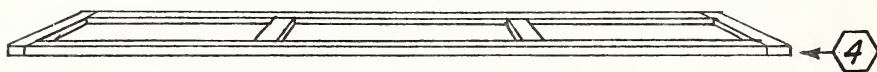
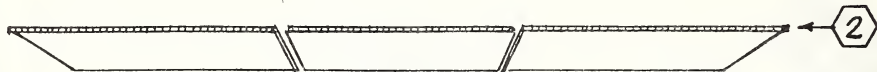
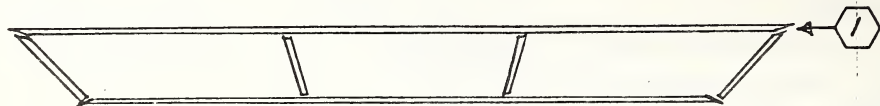
AN AUTOMATIC "AIR-SHOCK"-ACTUATED VENT SYSTEM.

CONCEPT BY TOM RILEY

DRAWN BY R. CORBETT 1978

VENT OPERATOR SCHEME
(FROM ORIGINAL PROPOSAL).

FIGURE 3



- ① PVC CLAMPING BAR
- ② CY/RO "ACRYLITE SDP" = "EXOLITE" @ 4'-0" STD. WIDTHS.
- ③ CY/RO ALUMINUM GLAZING BAR W/STAINLESS ST. SCREWS @ 1'-0" O.C.
- ④ 1X2 PINE FRAME - TWO $\frac{3}{8}$ " X 4" DOWELS & GLUE @ JOINTS.
- ⑤ 1X4 PINE FRAME W/ 1X6 FLANGE ENDS FOR NAILING - DOWEL JOINTS

NOTE:

WEATHERSTRIP SHOULD BE LOCATED ON THE UNDERSIDE OF ④, RATHER THAN ON TOP OF ⑤, TO KEEP IT OUT OF THE WEATHER."

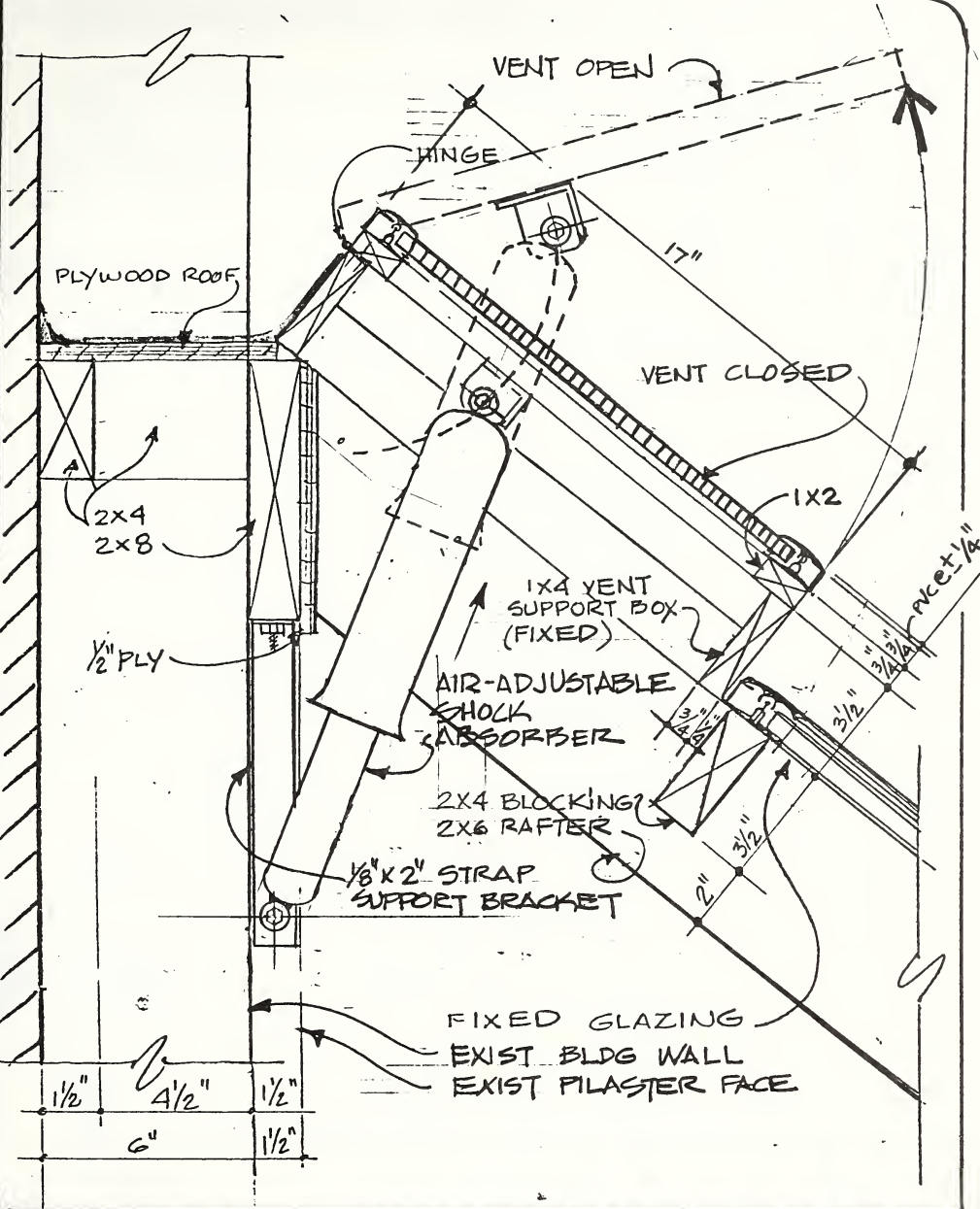
THE OXO FOUNDATION

SUBJECT:
EXPLODED VIEW: VENT & FRAME.

P. O. BOX 3706
BUTTE, MONT. 59701

DATE: 1/20/80
SCALE: NONE

FIG.
4



THE OXO FOUNDATION

SUBJECT:

SECTION THRU VENT @ APEX.

RLC

P. O. BOX 3706
BUTTE, MONT. 59701

DATE:

1/20/80

SCALE:

3"=1'-0"

FIG.
5

from Lee's Speed Shop, 2222 Amherst, Butte, Montana 59701, for \$59.95 per pair. I fabricated very simple mounting brackets of one-eighth inch by two inch steel strap.

A schematic of the final vent controller mechanism as designed by engineer, Tom Riley for the project is shown in Figure 6, and materials list for the system is shown in Figure 7.

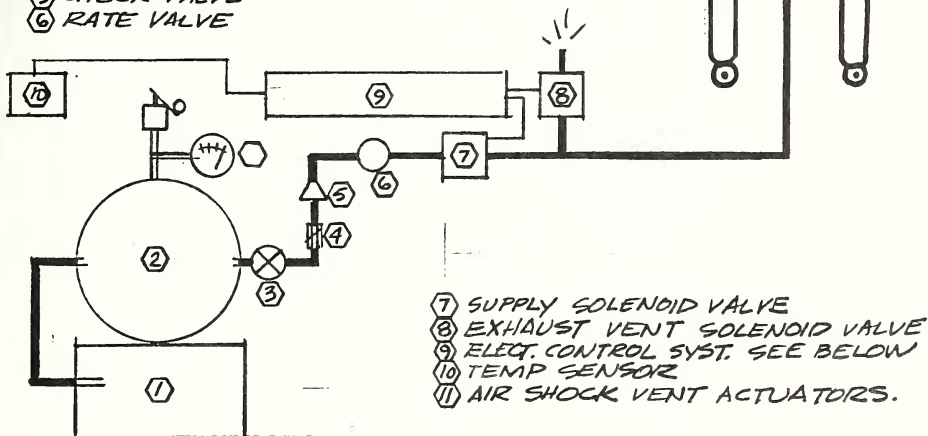
Note:

One of the problems in using automotive air-adjustable shock absorbers for vent actuation is that you are limited to "off-the-shelf" load capacity and extension length. To fully utilize the shocks with these two parameters given, one must carefully adjust the geometry of the relationship between shock mounting points, hinge point, and desired vent arc travel to fall within the limitations of shock stroke and lifting power. This can be a rather tedious process of trial and error, involving some real heady mathematics. In designing the vent system for this project, Tom Riley developed a calculation routine which accomplishes the job of designing the mounting relationships, and reduced the program to magnetic card form for use in Texas Instruments programmable hand-held calculators. For the information of those who wish to pursue this matter, the mathematics and programming are included in Appendix 2.

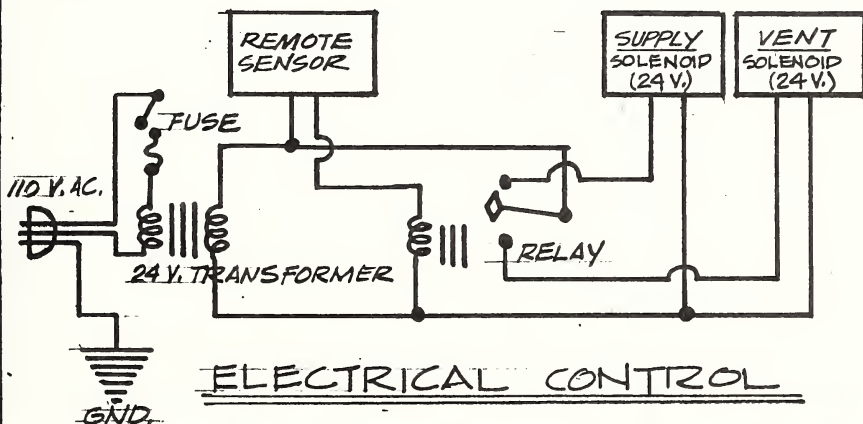
Persons wishing to use the magnetic card program for design work are urged to contact the grantee.

Before leaving the subject of vent control actuators, it might be helpful to point out that the system described herein, although it performs beautifully, is probably not realistically applicable to smaller greenhouses of more conventional residential scale. For those designing smaller greenhouses and wishing to minimize non-renewable energy input and yet achieve some amount of independence from hand-operated venting, it

- ① COMPRESSOR, 1/2 HP, 1.5 SCFM @ 40 PSI - (MAX 100 PSI)
- ② AIR TANK - 7 1/2 GAL.
- ③ SYSTEM VALVE
- ④ QUICK-DISCONNECT - (ALLOWS OTHER USE OF AIR)
- ⑤ CHECK VALVE
- ⑥ RATE VALVE



AIR SYSTEM



THE OXO FOUNDATION

SUBJECT: VENT ACTUATOR SCHEMATICS

P. O. BOX 3706
BUTTE, MONT. 59701

DATE: 1/20/80 SCALE: NONE

FIG
6

MATERIALS

<u>Item</u>	<u>No.</u>	<u>Description</u>
1	1	Compressor - 100 psi max. low-flow rate
2	1	Tank - 1 ft ³ 125 psi max.
3	2	Check valves
4	1	Pressure control valve with relief
5	1	Gauge 0-150 psi
6	1	Relief valve 100 psi
7	1	Valve Gate
8	1	Valve
9	1	Quick disconnect
10	1	Flexible hose $\frac{1}{4}$ ID 2 ft.
11	2	Solenoid, 24 volt
12	1	Vent Control Valve
13	1	Transformer 24 volt
14	1	Thermostat remote sensing
15	1	Relay 24 volt DP DT
16	1	Switch SPST
17	1	Fuse Holder
18	1	Fuse .5 amp
19	2	Line Cords three wire
20	1	Box

GREENHOUSE VENT CONTROL SYSTEM MATERIALS LIST

FIGURE 7

might be more economically justifiable to consider thermally activated vent mechanisms. Though these are limited in lifting power to relatively lightweight vents, they work. Two such products, the Solarvent and the Dalen Series 35, are shown in Appendix 1, and are available in this region from Energy House, P. O. Box 5288, Salem, Oregon 97304. Tele: (503) 364-7718.

7. Air Handling - The installation of the fan for air movement from the apex of the greenhouse to the residence was accomplished without incident. The fan will operate daily when excess heat is available in the greenhouse at a rate determined by the fan speed controller, which can be "fine tuned" by manual setting on a seasonal basis; perhaps every two months. The manufacturers' literature on the air movement system is presented as Appendix 4.

8. Floor - As the discerning reader will note, the order of this report on the major elements of the project correspond to the chronological order of construction. Thus, the floor came last in the process. This is a direct result of the problems experienced due to inclement weather. In other words, the first order of business was to enclose the structure, leaving the vent operators, air handling equipment and floor till last, so that installation of these elements would be "inside work", and not weather-dependent.

With regards to the floor as finally installed, it was necessary to make a change from the design contained in the original proposal. This change was dictated in part by economics, and in part due to a closer look at the thermal configuration. The rationale for this change was submitted to DNRC for their consideration and final approval. This material appears as Appendix 3.

7B. SYSTEM INSTALLATION

The original proposal was for grant funds to cover "materials only", and the labor for the project was donated by the grantee. As part of the process a detailed (20 pages) construction diary was kept, with person-hours recorded on a daily basis, and milestones recorded as the project evolved. With the exception of delays caused by inclement weather, the project progressed with general conformance to the timetables projected in the original proposal. While space prohibits a detailed account of the construction time involved, the following figures and dates, gleaned from the construction diary, show relative levels of effort involved in accomplishing the major elements of the project. (See Figure 8.)

It should be noted that although the total construction time logged in the project diary is around 1200 hours, all of the work was by "amateurs", and was for the most part accomplished after a regular 8-hour work day or on weekends, spread over nearly ten months. If this project had been built by a professional contractor with professional labor working continuously and in good weather, it is anticipated that surely the total duration, (and perhaps even the total person hours) involved would decrease significantly.

Of particular interest with regard to time is the fact that the entire structure was "double glazed" in a period of two days. This fact highlights one of the distinct advantages of (and reasons for using), the CY/R0 Acrylite SDP glazing system. Although there is a fair amount of preparatory time involved in getting ready to install the glazing; (i.e., drilling holes in and attaching the extruded aluminum glazing bars to the rafters), once actual installation starts it goes very rapidly. On the day the roof glazing was installed, with a full-time working crew of five people and a part-time moral support/observation crew of seven people, we timed the cycle

of installing the glazing sheets and found that it took only 14 minutes per 4' x 16' sheet. Even with rest breaks and movement of scaffolding included, we found it took a little over eight hours to install nearly 1000 square feet of glazing. Given the alternatives (thermo-pane glass units which would have been much heavier and harder to handle, or fiberglass-reinforced plastic in roll stock which would have entailed much more time and labor to install with battens), it is my opinion that the selection of ACRYLITE SDP was one of, if not THE, critical factors in accomplishing this project.

This is not to say that there weren't some interesting problems encountered in glazing this structure however. By examining the drawings in Exhibits 5 and 6, the reader will note that this is a relatively large structure, and that the PVC clamping bar of the Acrylite SDP glazing system installs from the outside. These two facts combined to pose the problem of gaining access to the glazing surface from the outside, high above the ground, to be able to pound the PVC clamping bars into place. While narrower width glazing materials might have permitted working from scaffolding inside the building and reaching across each sheet to fasten it to the previous rafter, this would have in any case been cumbersome, and the four foot width of Acrylite proved to be beyond reasonable reach. Of course, a boom truck and platform, or a "cherry-picker" would have solved the problem, but not inexpensively. After much cogitation and after rejecting the offer of a mountaineering friend to rappel down the structure from above, we (that is, my father) hit on the elegant and free solution of constructing a "ladder truss" to lean against the building just above and parallel to the roof glazing. This was built in one-half hour from scrap lumber, and cleats on its top surface allowed my 140-pound brother to climb up the roof with ease to pound the PVC clamping bars into place with a rubber mallet.

Close examination of the cover of this report and of Exhibit 3 will show this process. (Note in Exhibit 3 that the lower end of the "ladder truss" is in the bed of a pickup truck for easy movement. The top of the unit was moved along the building from scaffolding within the structure through the open vents. Because prevailing winds at the site are from the West, the glazing was installed from West to East, to minimize the chance of the partially glazed structure acting like a wind scoop and lifting off.

In short, the reader is cautioned to carefully plan out the construction sequence and strategy well in advance of actual building. Frankly, the problem of exterior access to the glazing did not appear as difficult to me when I drew the plans long ago as it did when the actual day arrived. While in this case, we were able to do some creative thinking to make things easier, it could easily happen that forgetting about something like this could easily cause significant cost over-runs.

<u>BUILDING ELEMENT</u>	<u>START DATE</u>	<u>FINISH DATE</u>	<u>PERSON HOURS</u>
1. Excavation & Backfill	7/22/78	9/26/78	56
2. Footings	8/15/78	8/16/78	16
3. Foundation	8/20/78	9/26/78	93
4. Framing	9/30/78	7/13/79	406
5. Glazing	7/14/79	7/15/79	221
6. Venting	5/7/79	5/22/79	105
7. Air Movement	12/26/79	12/28/79	51
8. Floor	10/7/79	10/29/79	112
9. Painting	(Interspersed throughout proj.)		76
10. Miscellaneous (*)	(interspersed throughout proj.)		<u>67</u>
	TOTAL		1203

* (Includes transporting of materials, wiring, writing reports, and design time, etc.)

BREAKDOWN OF TIME AND DATES FOR SYSTEM INSTALLATION

FIGURE 8

7C. SYSTEM TESTING AND MODIFICATION

1. Thermal Gain/Heat Loss - As of this writing the system is performing generally within the realm of expectations. Testing thus far has been minimal due to the short time between completion of construction and writing this report. Daily observation of a maximum-minimum thermometer indicates that the greenhouse/solarium temperature at 24 inches above the floor is "bottoming out" at about 30°F above outside ambient lows, and is "peaking" at about 70°F above outside ambient highs. This is to say that in late December 1979, during relatively mild sunny days and cold nights, temperature swings of 80°F (from 30°F to 110°F) were experienced. During this time the fan was not yet operational, so heat transfer from the solarium to the residence was limited to the radiative component passing through the concrete wall separating the two spaces.

One would suspect two factors to be involved in producing such a wide diurnal swing in temperature:

The first is an apparent lack of sufficient mass coupled with the greenhouse to store energy during the day (bringing peaks down) and re-radiate it to the space at night (bringing minimums up). A partial explanation is the high heat loss rate due to the extremely large glass area (over 1340 square feet).

The second is the possibility that the thermal mass contained in the very large (13' x 12') "buttresses" in the corners of the residence (i.e., on the east and west ends of the backwall of the solarium) are acting either as much larger "heat sinks" than anticipated, or are conducting heat around the heavily insulated solarium walls and dissipating it to the exterior from the east and west faces of the building itself.

My suspicion is that a combination of these two affects is the actual case. To rectify the situation I have mapped out three courses of action, which will be pursued as time and money permit:

(A) Increased Thermal Storage:

I have already purchased (at my own expense), sixty 55 gallon drums which, when filled with water, painted black, and stacked two high along the north wall of the solarium, should do much to moderate the large temperature excursions.

(B) "Third Layer" Glazing or Night Insulation:

Either of these two strategies would help to maintain higher internal temperature minimums by decreasing the significant nighttime losses experienced with such a large glazing area. Of the two, the addition of a third layer of glazing would be by far the easiest and cheapest for this building. It is likely that I will run the building "as is" but with the additional thermal storage for a year or two, then consider one of the inexpensive film glazings such as 3M Company's Flexigard 3410 as a retrofit third glazing layer, attached to the existing solarium rafters inside of the Acrylite SDP glazing.

(C) Exterior Insulation at East and West Walls of Residence:

Probably the least expensive (and least effective) strategy would be to apply protected rigid insulation on the exterior of concrete corners of the east and west ends of the residence to decrease the possibility of heat escaping by this conductive "short circuit." This strategy would not, however, decrease the peaking temperatures in the solarium, so it will only be tried after strategies 1 and 2 above.

2. Venting - The venting system works beautifully. I am anticipating that it will be very seasonal in operation; that is, it will only operate from about June to September. The only modification to the original proposal has been the addition of "intake" vents along the bottom of the kneewall at the south.

While I still feel that intaking air from the two circular endwall windows and the entry would have been sufficient to create enough of a chimney effect to exhaust sufficient air at the upper vents to prevent overheating, these lower vents were added partially as a precaution against having insufficient intake air and partially as a security measure. They are basically a continuous six inch screened gap between the sill plate and the lower edge of the vertical kneewall glazing. By providing nearly 25 square feet of intake air they will permit locking the windows and entry door when no one is home.

3. Air Handling - The only modification made to the air handling system was changing (at my own expense) from the propellor-type fan shown in the original proposal to a squirrel-cage type. This was done solely for noise reduction. The noise of a fan is a function of tip speed and going from a fairly large diameter propellor type to a cabinet ventilator containing two smaller squirrel-cage blades reduced tip speed and noise tremendously. It was felt that this and the better quality of construction of the cabinet ventilator justified the additional cost.

7D. SYSTEM PERFORMANCE

In accordance with the DNRC's Guidelines for Preparation of Grant Proposals, the original application for funding contained no provision for monitoring system performance. Because of this and because this report is being written simultaneously with final construction "wrap-up" of the project, there is no specific performance data available at this time. However, several points in this regard are worth mentioning.

A fair analysis of the useful heat delivered to the residence to which this project is attached can only be made when the residence is at it's optimum level of heat retention. That is to say I'm afraid I've violated my own guiding principle on solar: "Weatherize before you solarize!" Because of the timing of this grant, I've had to stop work on remodelling the interior of the structure to build the solarium addition. This means that the main structure is not at present as tightly constructed and as well insulated, as it should be. Thus beneficial heat gained from the project system can be lost from the residence. Now that the grant project (and this report) is finally finished, I can re-direct my efforts at making sure the building retains heat gained from the system as long as possible. Caulking, weather-stripping, and insulation are all part of the plan in the months to come. This fact, coupled with projected system modifications listed in Section 7C, means that the net result of adding this sytem to this residence may not be in measurable form for another year.

However, there are obvious yet unquantifiable ways in which the solarium is performing beyond expectations already. It is hard to calculate the pleasure derived from adding a 700 square foot addition that is independent of the utility grids for its heat, and the feeling of sitting in the solarium watching the temperature edge toward 90°F while it's 20°F outside is indeed immeasurable. I can also report a distinctly heightened awareness of weather and solar conditions as a result of living and working in and with this project.

On a more scientific note, I am recording fuel usage for space heating, as well as electrical power usage so that when all systems are "go", I will have lots of background data with which to make comparisons.

One final word about the system performance of the vent operators: They work so beautifully that I'm sure I've cycled them more times already to show friends and visitors than they'll ever cycle by themselves to vent the solarium!

7E. SYSTEM COST

This project experienced an increase in cost over the budget estimate prepared for the original proposal of 15.7 percent. The monetary difference of \$1125.06 was contributed by the grantee. While a cost increase of this size is within reason for preliminary budgets prepared over a year from completion of construction, especially when inflation is in the double-digit range, a closer examination of where the cost increase came from is in order:

1. Glazing - There was no allowance for shipping charges on this item in the original proposal. The factory indicated that the then-current price of the glazing was \$1.81 per square foot, and that freight would be roughly \$.20 per square foot. Thus the estimate of \$2.00 per square foot was used. In the time between estimation and actual purchase, the price of the glazing was raised, to \$2.00 per square foot; (it's even higher now), leaving no margin with which to absorb shipping costs.

Additionally, the glazing supplier refused any but cash terms of sale. Thus the grantee had to borrow the money for glazing on a short term note, incurring an interest charge which added to the cost of the glazing. These factors combined to an amount of \$409.09, or over 36 percent of the cost increase.

2. Electrical - There was no allowance for power distribution or lighting in the original proposal. The cost attributed to these items has been included in the final report in the interests of completeness, adding a cost of \$343.36 or over 30 percent of the cost increase.

3. Increase in Quality - Decisions made by the grantee to spend more (of his own) money on the fan and the entry doors added another \$219, or over 19 percent of the cost increase.

Deducting the above three items, which were not in the original budget, from the final cost for comparison purposes leaves the final (adjusted) project cost within 2 percent of the estimate prepared for the original proposal almost two years ago!

As is noted above, the cost increases were all borne by the grantee. A detailed final budget breakdown and summary appears in Figure 9.

FIGURE 9

Grant #RAE-054-COBT-781

DETAILED FINAL BUDGET

	<u>Grant</u>	<u>Other</u> (From Grantee)	<u>Total</u>
<u>I. SALARIES (not applicable)</u>			
<u>II. OPERATING EXPENSES</u>			
<u>A. Contracted Services</u>			
1. Tom Riley (Engineer) (10 hours @ \$25)	\$ 125.00	\$ 125.00	\$ 250.00
2. Excavation (Backhoe) (8.8 hours @ \$12.50)	110.00	-0-	110.00
3. Film Processing	-0-	20.00	20.00
Subtotal (Services)	\$ 235.00	\$ 145.00	\$ 380.00
<u>B. Supplies and Materials: "Solarium"</u>			
<u>1. Footing, Foundation and Floor</u>			
<u>a. Concrete, as follows:</u>			
26 sacks Portland @ 4.64	-	\$ 120.64	\$ 120.64
7.5 yd. gravel @ 10.20	-	76.50	76.50
4.5 yd. sand @ 10.83	-	48.74	48.74
<u>b. Mortar for conc. blocks:</u>			
2500 lb. sand @ .48	-	12.00	12.00
3 sacks masonry @ 3.63	-	10.89	10.89
<u>c. Reinforcing</u>			
140 LF #3 @ .12	-	16.80	16.80
120 LF 6" Durowall @ .12	-	14.40	14.40
<u>d. Concrete Blocks (6"):</u>			
156 common @ .51	-	79.56	79.56
75 Bond Beam @ .51	-	38.25	38.25
10 Halves @ .35	-	3.50	3.50
Delivery Charge	\$ 5.00	-	5.00
<u>e. Anchor Bolts</u>			
42 incl. washers, nuts, @ .92	-	38.64	38.64
<u>f. Perimeter & Slab Insulation</u>			
720 SF 2" Beadboard @ .28	201.60	-	201.60
208 SF 2" Moisture Proof @ .53	110.24	-	110.24
Freight for above (Great Falls)	20.10	-	20.10
2 Gal. Block Coating @ 2.20	4.40	-	4.40
Troll duct tape @ 5.85	5.85	-	5.85
5 shts. 1/4" Asbestos Bd. @ 19.70	98.50	-	98.50
Masonry Blade for above	-	2.19	2.19
1 Gal. Mastic @ 13.10	13.10	-	13.10
1 Tube caulk @ 2.19	2.19	-	2.19
60 LF Expansion @ .21	12.60	-	12.60
720 SF Vapor Barrier @ .04	28.80	-	28.80
<u>g. Used Brick</u>			
1170 @ .10	-	117.00	117.00

DETAILED FINAL BUDGET

Page Two

	<u>Grant</u>	<u>Other</u> (From Grantee)	<u>Total</u>
2. <u>Framing:</u>			
a. <u>Blocking</u>			
16 LF 1 x 4 @ .44	\$ -	\$ 7.04	\$ 7.04
352 LF 2 x 4 @ .245	-	86.24	86.24
b. <u>Plates</u>			
156 LF 2 x 8 @ .57	-	88.92	88.92
c. <u>Studs</u>			
420 LF 2 x 6 @ .25	105.00	-	105.00
d. <u>Rafters</u>			
306 LF 2 x 6 @ .42	-	104.00	104.00
e. <u>Sill Sealer</u>			
73 LF @ .08	5.84	-	5.84
f. <u>Nails</u>			
15 lb. #16 Comm. @ .55	-	8.25	8.25
19 lb #16 Galv. @ .70	-	13.30	13.30
70 concrete shots @ .485	-	33.95	33.95
g. <u>Saw Blade</u>			
1 carbide	-	10.79	10.79
h. <u>Water Level</u>			
40 LF plastic tube @ .22	-	8.80	8.80
3. <u>Insulation</u>			
a. 552 SF 5½" x 23" Foil @ .248	137.43	-	137.43
b. See Section 1 Above for Rigid			-
c. 1 Can Foam Sealer	7.29	-	7.29
4. <u>Sheathing and Flashing</u>			
a. 12 shts 5/8 CDX @ 11.73	-	140.76	140.76
b. 12 shts 3/8 CDX @ 9.92	-	119.04	119.04
c. 21 shts Lath @ 3.38	-	70.98	70.98
d. 7 sacks portland @ 4.95	-	34.65	34.65
e. 6 sacks Lime @ 3.35	-	20.00	20.10
f. 6 lb. blued nails @ .50	-	3.00	3.00
g. 52 LF Casing Bead @ .33	-	17.16	17.16
h. 72 LF Corner Bead @ .24	-	17.28	17.28
i. 90 LF "2" Flashing @ .43	38.70	-	38.70
j. 64 LF Rain Drip @ .25	16.00	-	16.00
k. 5 lb. galv. strip @ .75	3.75	-	3.75

DETAILED FINAL BUDGET

Page Three

	Grant	Other (From Grantee)	Total
5. <u>Glazing System</u>			
a. 1324 SF CYRO Acrylite @ 2.00	\$2648.00	-	\$2648.00
b. 450 LF Alum. (Edge) @ .95	427.50	-	427.50
c. 325 LF Alum. (Mid) @ .75	243.75	-	243.75
d. 180 LF Alum. End Cap @ .25	45.00	-	45.00
e. Freight on (A) above	298.62	-	298.62
f. Freight on (B) (C) (D) above	62.52	-	62.52
g. Adjustment for Shipping Damage (Deduct)	(25.00)	-	(25.00)
h. Interest on 90 day note for all above required while waiting for drawdown of state grant funds	47.95	-	47.95
i. 1000 #8 x 1 1/4" stainless screws @ .085	85.00	-	85.00
6. <u>Finishing</u>			
a. 6 gal. Tinted Oil Base Primer @ 8.25	49.50	-	49.50
b. 8 gal. Tinted Latex Final @ 10.91	87.28	-	87.28
c. 5 gal. Flat Black Latex @ 7.20	36.00	-	36.00
d. 6 tubes caulking @ 1.49	-	8.94	8.94
e. 1 Double entry door (used)	-	120.00	120.00
7. <u>Ductwork</u>			
a. Galv. sheet metal fabrication	-	14.00	14.00
b. Misc. sheet duct	-	24.00	24.00
c. Screws	-	1.09	1.09
8. <u>Electrical</u>			
a. 2 rolls 12/2 Romex @ 24.59	-	49.18	49.18
b. 1 roll Burial 12/2 @ 33.00	-	33.00	33.00
c. 7 oversize outlet boxes @ 3.99	-	27.93	27.93
d. 7 cover plates @ .79	-	5.53	5.53
e. 11 Conduit connectors @ .89	-	9.79	9.79
f. 5 switches @ 2.64	-	13.20	13.20
g. 5 switch plates @ .27	-	1.35	1.35
h. 11 Standard outlet boxes @ .69	-	7.59	7.59
i. 7 Light fixtures @ 27.97	-	195.79	195.79
j. No charge for salvaged conduit	-	-	-
Subtotal (Expenses)	\$5057.51	\$2148.28	\$7205.79
C. <u>Communications</u> (Not Applicable)	-	-	-
D. <u>Travel</u> (Not Applicable)	-	-	-
E. <u>Rent</u> (Not Applicable)	-	-	-

EQUIPMENT

A. Air Handling System

1. Penn Ventilator Co.; 1/2 hp squirrel-cage fan & cabinet #2-14 Zephyr	255.00	99.00	354.00
2. Variable Speed solid state controller for fan - Penn Ventilator Co. #LT-40	25.00	-	25.00
3. Thermostat controller w/remote sensing Rho Sigma #S500	75.00	0	75.00

<u>Grant</u>	<u>Other</u> <u>(From</u> <u>Grantee)</u>	<u>Total</u>
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B. Vent System1. Vent Framing:

a. 128 LF 1 x 2 #2 common @ .125	\$ 16.00	\$ -	\$ 16.00
b. 96 LF 1 x 4 D Pine @ .39	37.44	-	37.44
c. 16 LF 1 x 4 #2 Common @ .19	3.04	-	3.04
d. 16 LF 1 x 6 #2 Common @ .35	5.60	-	5.60
e. 48 LF 2 x 2 x 1/8 Angle @ .50	24.00	-	24.00
f. Fabricate Support Clips	7.50	-	7.50
g. 8 Bolts - 9/16 x 3 1/2 w/nuts @ 1.33	10.64	-	10.64
h. 2 cans spray paint @ 2.10	4.20	-	4.20
i. 1 Bottle muriatic acid @ 1.25	1.25	-	1.25
j. 10 pr. hinges @ 1.19	-	11.90	11.90

2. Vent Actuator System

a. Sears Model 106 single cylinder tank air compressor - 1/2 hp	140.67	-	140.67
b. 2 pr. Gabriel "Hi-Jacker" Air Adjustable Shock Absorbers #39106 with hose kit #140510 @ 59.95	119.90	-	119.90
c. 5 copper 90's (1/2") @ .53	2.65	-	2.65
d. 6 copper sleeves (1/2") @ .04	.24	-	.24
e. 4 copper tees (1/2") @ .68	2.72	-	2.72
f. 60 LF 1/2" copper tubing Type L @ .37	22.20	-	22.20
g. Miscellaneous Brass fittings for lines	-	22.51	22.51
h. Air pressure guage	-	4.65	4.65
i. Pressure control valve	-	7.40	7.40
j. Relief valve	-	3.85	3.85
k. Quick disconnect @ 2.08	-	2.08	2.08
l. 2 Solenoid valves (24 volt) @ 14.77	-	29.54	29.54
m. 24 volt transformer @ 5.09	-	5.09	5.09
n. Cooling thermostat (24 volt) @ 11.88	-	11.88	11.88
o. 24 volt relay @ 7.58	-	7.58	7.58
p. Switch @ 1.35	-	1.35	1.35
q. Fuse and holder	-	1.65	1.65
Subtotal (Equipment)	\$ 753.05	\$ 208.48	\$ 961.53

ADMINISTRATIONA. BookkeepingSubtotal (Administration)

\$ 100.00	\$ -	\$ 100.00
\$ 100.00	-	\$ 100.00

DETAILED FINAL BUDGET
Page Five

	<u>Grant</u>	<u>Other</u> <u>(From</u> <u>Grantee)</u>	<u>Total</u>
<u>BUDGET SUMMARY</u>			
I. SALARIES	\$ - 0 -	\$ - 0 -	\$ - 0 -
II. OPERATING EXPENSES	\$5057.51	\$2148.28	\$7205.79
III. EQUIPMENT	\$ 753.05	\$ 208.48	\$ 961.53
IV. ADMINISTRATION	\$ 100.00	\$ - 0 -	\$ 100.00
<u>GRAND TOTAL</u>	<u>\$5910.56</u>	<u>\$2346.76</u>	<u>\$8267.32</u>

NOTE: All labor supplied by Grantee

7F. ECONOMIC EVALUATION

Because the system performance has not been measured as of this writing, and because the residence is not as yet in shape to minimize the heating load to which the system will contribute, it is merely conjecture to evaluate the economics beyond the level of the analysis contained in the original proposal.

Generally, it can be said that the system appears to be performing reasonably and as expected, (see Section 7C), but "fine tuning" remains before system performance can be measured with any accuracy.

A not-so-obvious benefit of the system, aside from its contribution to the reduction of heating bills for the residence is the amount of additional living space it provides. Because of it's size, it offers plenty of enjoyable space for "living" in addition to growing vegetables and house plants.

8. CONCLUSIONS AND RECOMMENDATIONS

Although the translatability of this project is hindered by virtue of the fact that it starts with a very unique and definitely non-standard residence, I do feel that it is successful in several respects. As a demonstration project, it is the largest attached greenhouse that I am aware of in Montana, if not in several surrounding states. It's use of the double-skin acrylic glazing sets it aside as one of very few places in Montana one can see this product in use. This is significant in my opinion because this glazing is one of, if not the only, glazing alternatives between the rather inexpensive and short-lived films and long-lived but expensive double glazed glass units. In addition, the vent operators are quite remarkable in their simplicity, quietness of operation, and uniqueness.

As adjustments are made to the thermal performance characteristics of the system, (see Section 7C), I am quite sure that this project will be one of the most unique examples of passive/hybrid solar architecture in the Northwest.

The reader who is contemplating the design and construction of an attached solar greenhouse is, however, cautioned from direct use of the design of this project on several accounts:

A) Shading - It is quite likely that the design as built in this project would seriously overheat when attached to a standard wood frame house. The knowledgeable observer will note the absence of any overhang or opaque roof section for shading in the summer. While almost certainly required in a more conventional context, this was intentionally omitted in this project because the heavy concrete walls of the residence lend enough thermal mass to the living space that overheating is never a problem. In fact, the structure is so massive that diurnal temperature swing in the living space without any heat added is

negligible, and annual variation (about 32°F), is such that the building can require heating even in summer. Because this is rarely the case with wood-framed structures, some judicious placement of shading is in order for attached greenhouses to be built onto these structures.

B) Purpose - For those contemplating an attached greenhouse it is important to be aware of what purposes are to be met by the structure. If plants are to be kept alive all year in the greenhouse, one might end up with a design which requires the addition of backup heat to the greenhouse in the winter, either by a separate heating system or by taking heat from the house. This could easily bring much higher fuel bills than heating the house alone. If, on the other hand, the object were to minimize the heating bills of the residence, and the greenhouse could be run cooler for several months in the winter, (i.e., planting was discontinued), then the resultant design would be quite different from the previous one. This project is more of a compromise; it is intended for space heating of the residence, as well as providing a comfortable and attractive addition to living space. For example, it may be that by filling and draining the water storage barrels on an annual basis, (i.e. emptying them in winter to overheat the greenhouse in the day and enable more hot air to be pumped into the residence), one could optimize heating benefits at the expense of sacrificing a few months of mid-winter growing season. On the other hand, it will be quite possible to leave water storage in place all year and, at the expense of heat supplied to the residence, keep plants alive in the greenhouse. By partitioning off areas in the greenhouse thermally, (i.e., with internal, double-glazed "box within a box" concepts, it should be possible to try both arrangements simultaneously. The point is that one should be of clear purpose before

designing and certainly before building.

C) Aperture - Although the extreme vertical size of this greenhouse was designed with an eye on the possibility of adding a loft or balcony level inside the solarium at a later date, it may prove to be cost ineffective, unless this is actually done. There are two reasons for this. First, the height obviously increased both structure and glazing cost by virtue of the sheer area involved. Secondly, this increase in glazing area or aperture causes a greater loss of heat back through the glazing than would be the case in a smaller greenhouse aperture. The point here is that in a more conventional attached greenhouse context, it would likely be more cost-effective to reduce the heating load of the residence by going to higher insulation levels and by building the envelope to be as air-tight in the first place, thus allowing a smaller and less costly aperture to be used.

9. MONITORING

During the next year or two it is anticipated that further refinement of both the thermal system and the heat retention capacity of the residence will bring the combination to a point where realistic measurement of energy flows can be done. Until such time as equipment and resources for monitoring system performance become available, logging of max-min thermometer readings and observations of fan usage, electrical consumption, and amounts of wood used for space heating will be continued manually.

As per the conditions of the grant, the DNRC may conduct an evaluation and monitoring program with respect to this project at anytime during the next five years.

10. PUBLIC AVAILABILITY

The most convenient time for public review of this project is on Sunday afternoons, but my rather hectic schedule necessitates that I request those wishing to visit the project call or write in advance to make arrangements.

11. PROGRAM EVALUATION

I am pleased to report I had no problems in dealing with DNRC's Renewable Energy Program and the folks who run it. All guidance received was clear and to the point and everyone was courteous and efficient in helping me with the procedures involved in drawing down grant funds.

The only troublesome areas I experienced were due to my own underestimation of the time involved, (it's hard to get a lot of work squeezed in after a full 8 to 5 routine), and a delay in receiving grant funds which I traced to computer problems in the State's then-newly-installed system.

All-in-all, I think the Renewable Energy Grant Program is performing an invaluable function, and I heartedly support its continued existence. Greater knowledge and increased implementation of renewable energy source utilization is essential, and with this program, Montana is in the forefront.

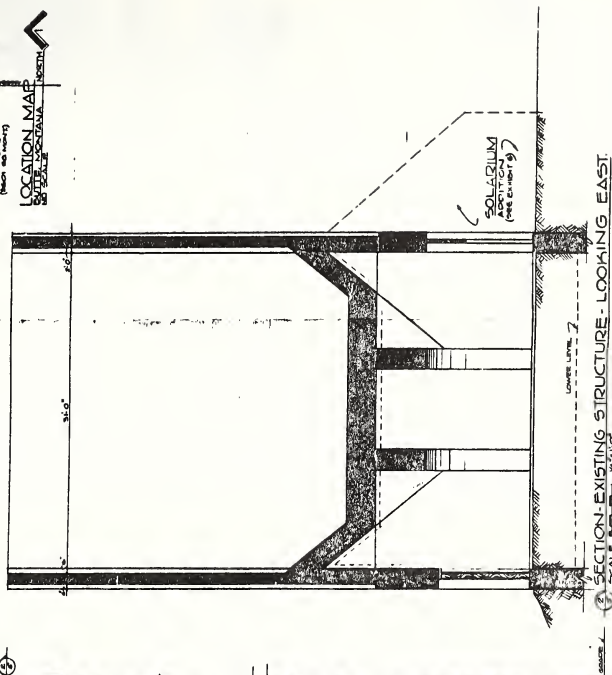
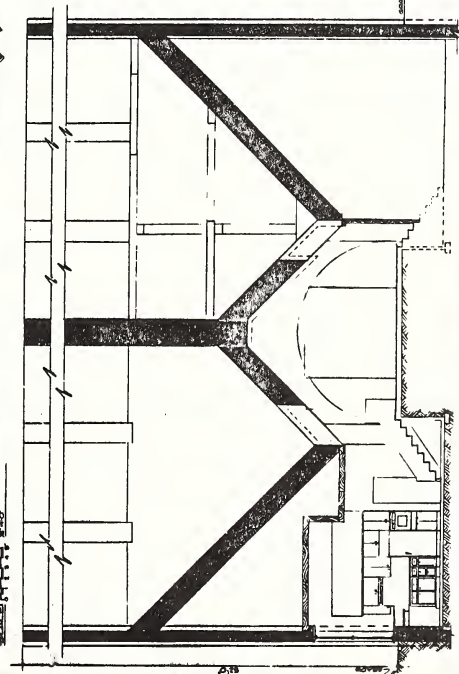
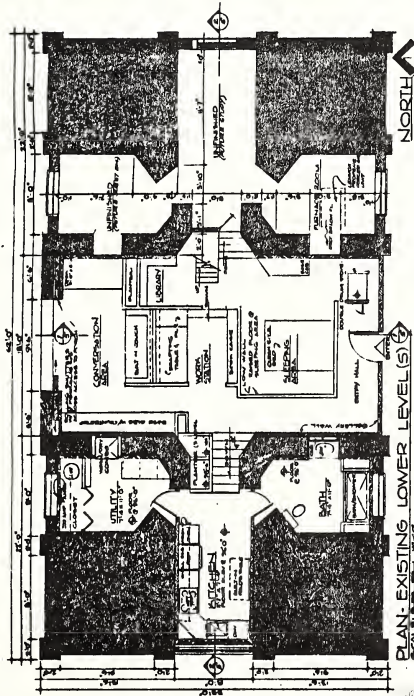


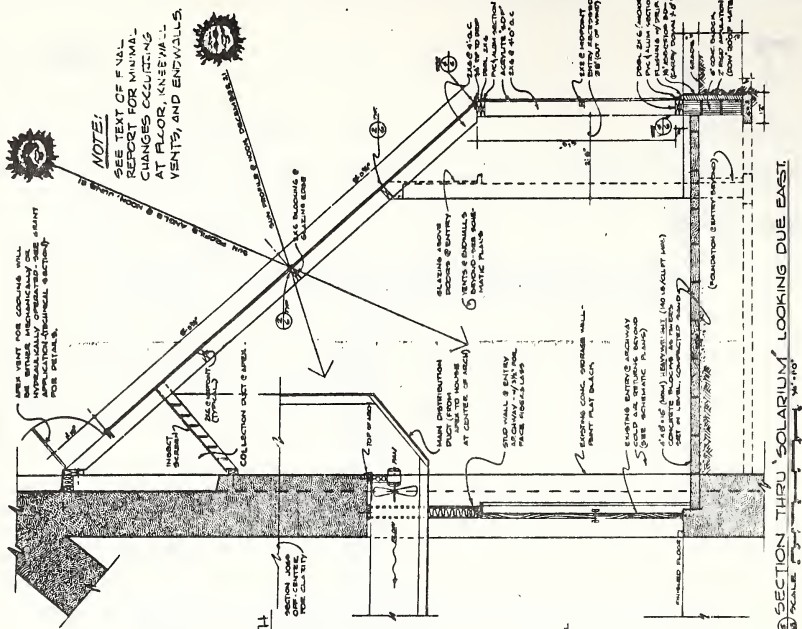
EXHIBIT 5

EXISTING STRUCTURE

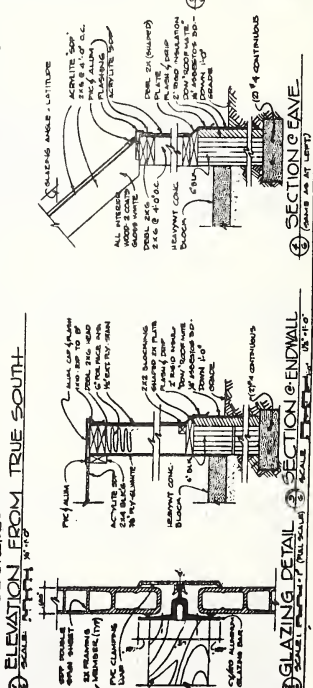
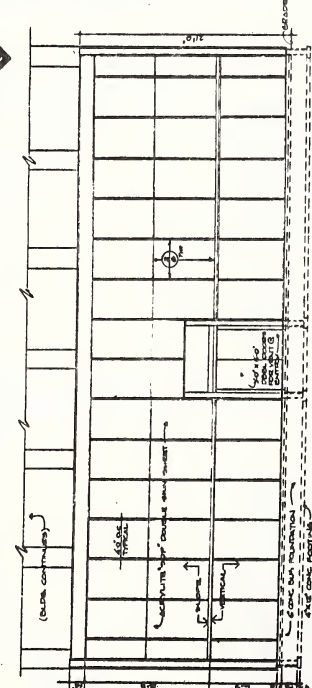
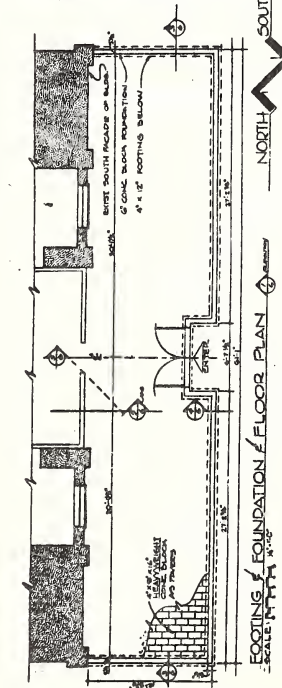
A RESIDENCE

3801 S.G. MONTANA ST. SUITE 101, MONTANA, NEARLY 5 CORNER

SCALE 1/4\"/>



NOTE:
SEE TEXT OF FINAL
REPORT FOR MINIMAL
CHANGES OCCURRING
AT FLOOR, KNEEWALL,
VENTS, AND ENDWALLS.



APPENDIX 1

Manufacturers' Literature: CY/RO Acrylite SDP
Double-Skinned Acrylic Glazing System.

PRODUCT SPECIFICATIONS

Standard Sizes

Thickness	0.630 in. $\pm$ 0.040 in. (16.0 mm $\pm$ 1.0 mm)
Width	47.250 in $\pm$ 0.160 in. (1200 mm $\pm$ 4 mm)
Lengths	8 ft. (2.4m), 10 ft. (3.0m), 12 ft. (3.6m), 16 ft. (4.8m) Lengths up to 20 ft. (6m) are available upon special request.*

* Custom lengths available when ordered in minimum quantity of 10 sheets in one size. A set-up charge applies for each custom length.

Skin Thickness	Approx. 0.067 in. (1.70 mm)
Rib Thickness	Approx. 0.053 in. (1.35 mm)

Composition & Materials	ACRYLITE SDP sheet is an extruded double skinned acrylic sheet in Clear, White or Solar-Bronze tints.
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Technical Data

Permissible* purlin distances (with purlins perpendicular to the ribs) for loads of:

	15	25	35	45 lbs./sq. ft.
Roof Glazing	50" (1.3m)	40" (1.0m)	33" (0.8m)	28" (0.7m)
Vertical Glazing	85" (2.2m)	56" (1.4m)	48" (1.2m)	40" (1.0m)

* For detailed Vertical Glazing Purlin Distances, please see Diagram $\approx$ 1004. For Roof Glazing Purlin Distances, please see Diagram $\approx$ 1005.

Permissible area load, vertical glazing (for standard sheet width, long sides secured)	14.0 lbs./sq. ft. (667.0 Pa)
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Permissible* bending moment relative to length—Support perpendicular to ribs

Roof glazing	31 ft. lb./ft. (140 Nm/m)
Vertical glazing	62 ft. lb./ft. (280 Nm/m)

* Maximum bending moment for ACRYLITE SDP acrylic sheet is greater than figures shown.

Support parallel to ribs (spaced at 45 in.)

Roof glazing	13 ft. lb./ft. (60 Nm/m)
Vertical glazing	26 ft. lb./ft. (120 Nm/m)

Heat transfer coefficient¹ (U)

Summer Conditions	0.55 BTU/hour/sq. ft./°F (3.2 W/m ² °C)
Winter Conditions	0.58 BTU/hour/sq. ft./°F (3.3 W/m ² °C)

Coefficient of linear thermal expansion (in./in. / °F. or °C.)

$$\alpha = \frac{40 \times 10^{-6}}{70 \times 10^{-6}} / ^\circ\text{C.}$$

Maximum service temperature without load

160°F. (71°C.)

Average Sound Reduction

23 dB

Flammability ACRYLITE SDP double skinned acrylic sheet is produced from an acrylic molding compound which is a combustible thermoplastic. Precautions used to protect wood and other combustibles from flames and high heat sources should also be observed with this material. Acrylic materials usually burn rapidly to completion if not extinguished. The products of combustion, if sufficient air is present, are carbon dioxide and water. However, in many fires sufficient air will not be available and toxic carbon monoxide will be formed, as it will from other common combustible materials. We urge good judgment in the use of this versatile material and recommend that building codes be followed carefully to assure it has been used properly. Access panels may be required for evacuation and venting of rooms glazed with ACRYLITE SDP. ACRYLITE SDP burns more rapidly than solid acrylic sheet. Noncombustible end caps must be used to prevent flame from contacting the open ends of ACRYLITE SDP acrylic sheet.

LIGHT TRANSMITTANCE AND COLORS

I.
Product
Specifications

The light transmittance of clear ACRYLITE SDP acrylic and CYROLON SDP polycarbonate sheets is nearly equal to that of double glazed glass (83%). Since SDP double skinned sheets are available in colors, a wide range of light transmission, solar energy transmission and shading coefficients can be achieved. Specific values are shown in the following chart:

Color	Light Transmittance (Approx.)	Shading Coefficient	Solar Transmission
ACRYLITE SDP Acrylic Sheet			
Clear	83%	0.97	83%
White (# 06531)	20%	0.31	19%
White (# 06310)	70%	0.81	67%
Solar-Bronze (# 43480)	52%	0.72	57%
Solar-Bronze (# 93201)*	24%	0.46	31%

CYROLON SDP Polycarbonate Sheet

Clear	73%	0.88	74%
White (# 99045)	9%	0.25	14%
Solar-Bronze (# LS 13-770)	21%	0.44	29%

*Solar-Bronze (= 93201) is not recommended for outdoor use because of high heat build up. For outdoor applications requiring these transmission values use CYROLON SDP Sheet = LS 13-770 Solar-Bronze.

SPECTRAL TRANSMISSION CHART

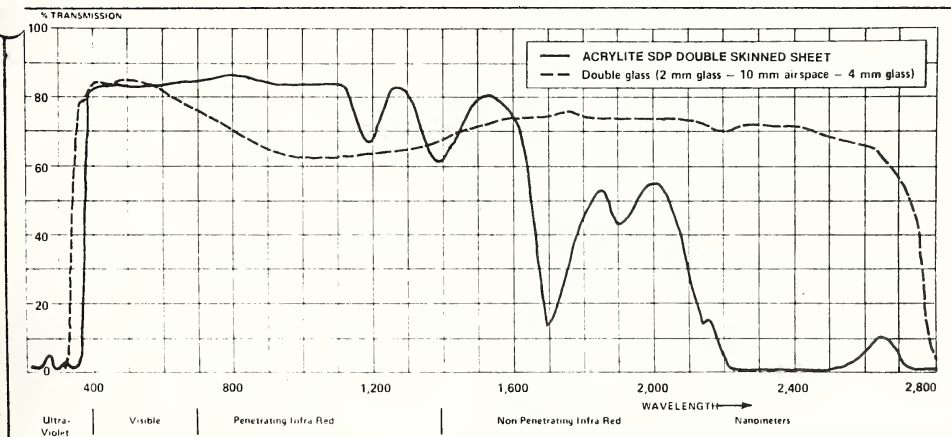


DIAGRAM # 1001

Availability

SDP double skinned sheets as well as glazing bar systems, completed fabrications (skylights, curtain wall systems, greenhouses) are available nationwide from a network of leading contract glazers, and fabricators. Additional engineering assistance is also available through the Market Development groups of both CY/RO Industries and Chemacryl Plastics Limited.

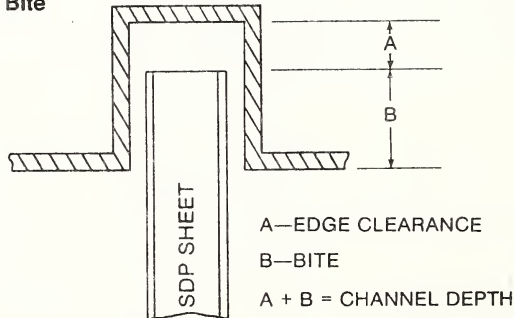
There are three basic alternatives for installing SDP double skinned sheet: 1) the CY /RO supplied glazing bar systems (APS-16, PVC/AL and UGS), 2) those designed for existing glass systems, and 3) custom designed configurations. Details of the CY / RO systems are outlined in Section 4. Should you decide to use other methods, we urge close adherence to the following considerations:

- expansion and contraction
- sealant and/or gasket system
- fastening methods.

Glazing Channel Depth

Some metal framing systems suitable for insulating glass of equal thickness can be used for SDP sheets. But because changes in temperature and humidity will cause greater expansion and contraction with SDP double skinned sheets than with glass, the glazing channel depth of the framing system must be adequate, as shown in Diagram #1002. Inadequate bite can cause the panel to pull out of the channel during contraction. Conversely, inadequate edge clearance can cause bowing of the panel during expansion. Gasket systems must allow for this movement so that "pumping out" and subsequent leakage will not occur. The Market Development groups of CY / RO Industries and Chemacryl Plastics Limited are available to assist you in the proper selection of a glazing system suitable for your particular application.

Edge Clearance Bite



Note: The lower edge of the panel sits on the bottom of the channel, therefore, the edge clearance values refer to the other three sides only.

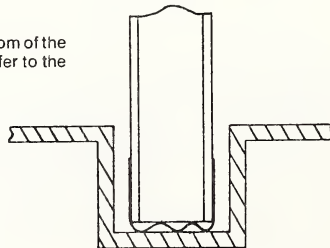


DIAGRAM # 1002

The channel depth is directly dependent upon the size of the panel. The longer the panel, the greater the thermal expansion and contraction. To determine this factor the following "rule of thumb" can be used:

For each three (3) feet panel length of SDP sheet a 100°F temperature differential will cause 1/8" of expansion and contraction. Edge clearance is determined using the following equation.

$$\frac{\text{Length of panel in feet}}{\text{Three (3) feet}} \times \frac{1''}{8} = \frac{\text{Panel size change for a } 100^\circ\text{F}}{\text{temperature change}}$$

The bite generally recommended for glazing SDP sheet is 3/4 to 1". Always allow for the maximum length the panel will expand to under the warmest expected condition.

Panel Length	A Edge Clearance	B Bite	A + B* Glazing Channel Depth
4	3/16	3/4	15/16
6	1/4	3/4	1
8	1/4	3/4	1
10	5/16	3/4	1-1/16
12	5/16	3/4	1-1/16
14	3/8	3/4	1-1/8
16	3/8	3/4	1-1/8
18	1/2	3/4	1-1/4
20	1/2	3/4	1-1/4

*These guidelines for channel depth assume no expansion/contraction condition in the glazing system itself. When this factor is calculated, there can be a reduction in the glazing channel depth since the system is expanding and contracting with the panel, though generally at a lower rate.

Example: When a 10' panel is installed on a cold day, make allowances for this "precontracted" condition by cutting the panel shorter. Conversely, on a hot day, make allowance for this "pre-expanded" condition by cutting the panel longer. Specific adjustments should be calculated using the above guidelines.

Sealants and/or Gaskets

We recommend dry-glazed rather than wet-seal systems whenever possible. Plastics have a higher coefficient of expansion than glass and wet seal systems normally used for glass are not appropriate. In addition, plasticizers sometimes found in sealants, particularly in the gun grade types, are usually not compatible with acrylic or polycarbonate materials and failure or leakage may result.

For panels shorter than 60 inches, and where absolutely necessary, a wet seal system may be used.

When this is mandatory, we recommend a silicone-based sealant. They are durable, remain elastic under most conditions and will not tear or shear under elongative or compressive movement.

All materials, sealants, cleaners, cementing solvents, etc. must first be checked for compatibility before using. Your representative will assist you if you have doubts about their suitability.

Point Fastening of the SDP Sheet is Not Recommended.

A proper glazing system should incorporate a perimeter clamping bar which will exert equal pressure, but will still allow the SDP sheet to expand or contract.

Glazing systems in *NEOPRENE rubber or other dark colored materials* should be avoided in SDP glazing systems. Their high heat absorption factor will result in high heat transfer to the SDP sheet beneath. Such uneven temperature build up will cause stresses that could ultimately lead to crazing.

Purlin Distances

Permissible purlin distances relative to live load requirements are outlined in Diagram # 1004 and # 1005. A space of 3/16" to 3/8" between the under side of the SDP sheet and the purlin will allow the sheet unrestricted deflection during the warmer months, and will give the required support to the SDP sheet when it is subjected to heavy snow load conditions.

Flashing

The SDP sheet should be clamped securely on **all** sides. If the calculated expansion tolerance is greater than the glazing channel depth of the header (top) extrusion, however, then a formed aluminum flashing with gasketing can be used in its place. See Diagram # 1003. The flashing should exert some pressure on the sheet to ensure weather tightness. Since the SDP sheet rests against the bottom extrusion, there is no need for allowances there. The bottom of the SDP sheet (with aluminum terminal section ATS-16 in place) can be retained at the $\frac{1}{3}$ points using "retainer clips," which will prevent the SDP sheet from slipping, as well as from lifting under wind or unequal pressure situations. This applies only if a continuous clamping bar is not possible.

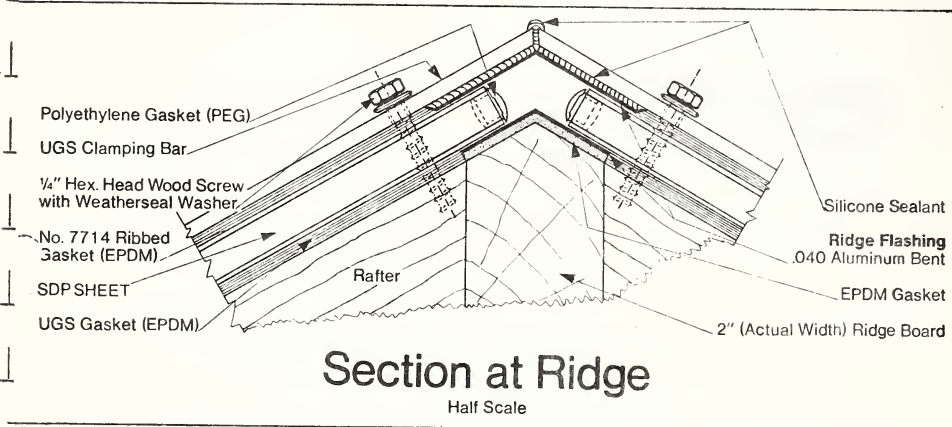


DIAGRAM #1003

Weep Holes

Assistance

- Provision for weep holes in the bottom glazing extrusion must be made to prevent condensation and infiltrating water within the glazing system and SDP sheet.
- Specific details of alternate glazing systems can be submitted to either CY/RO Industries or Chemacryl Plastics Limited Market Development groups for precise recommendations.

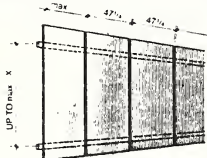
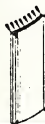
PURLIN DISTANCES FOR VERTICAL GLAZING

2.
Installation

VERTICAL GLAZING

PERMISSIBLE PURLIN DISTANCE X
WITH PURLINS PERPENDICULAR TO THE RIBS

INHERENT STIFFNESS



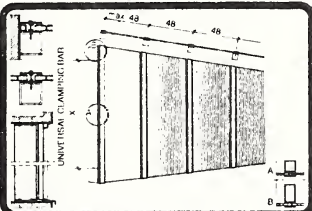
ACRYLITE SDP SHEET

CYROLON SDP SHEET

FOR LOADS IN lb /sq. ft

15	25	35	45	15	25	35	45
85"	56"	48"	40"	94"	60"	50"	48"
2.2 m	1.4 m	1.2 m	1.0 m	2.4 m	1.5 m	1.3 m	1.2 m

UNIVERSAL CLAMPING BAR (UGS)



WITH SUBSTRUCTURE B
NO PURLIN
WITHOUT SUBSTRUCTURE 85"

65"
1.65 m

58"

50"

75"

65"

60"

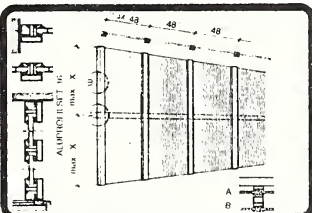
1.9 m

1.65 m

1.5 m

WITH SUBSTRUCTURE B
NO PURLIN
WITHOUT SUBSTRUCTURE 94"

APS 16



WITH SUBSTRUCTURE B
NO PURLIN
WITHOUT SUBSTRUCTURE 85"

65"
1.65 m

58"

50"

75"

65"

60"

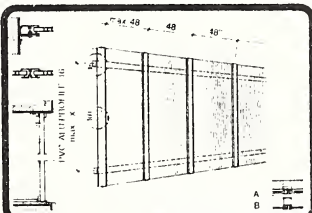
1.9 m

1.65 m

1.5 m

WITH SUBSTRUCTURE B
NO PURLIN
WITHOUT SUBSTRUCTURE 94"

PVC-AL 16 PVC-ALE 16



WITH SUBSTRUCTURE B
NO PURLIN
WITHOUT SUBSTRUCTURE 85"

56"
1.4 m

48"

40"

60"

50"

48"

1.5 m

1.3 m

1.2 m

WITH SUBSTRUCTURE B
NO PURLIN
WITHOUT SUBSTRUCTURE 94"

DIAGRAM # 1004

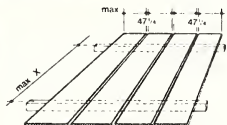
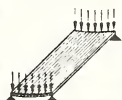
PURLIN DISTANCES FOR ROOF GLAZING

2.
Installation

ROOF GLAZING

PERMISSIBLE PURLIN DISTANCE X
WITH PURLINS PERPENDICULAR TO THE RIBS

INHERENT STIFFNESS



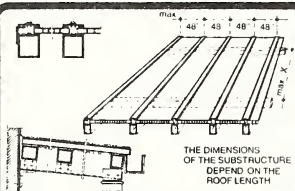
ACRYLITE SDP SHEET

CYROLON SDP SHEET

FOR LOADS IN lb./sq. ft.

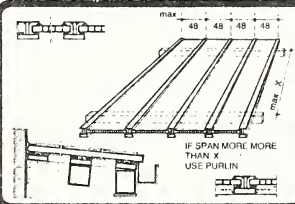
15	25	35	45	15	25	35	45
50"	40"	33"	28"	60"	45"	38"	33"
1.3 m	1.0 m	0.8 m	0.7 m	1.5	1.1 m	1.0 m	0.8 m

UNIVERSAL CLAMPING BAR (UGS)



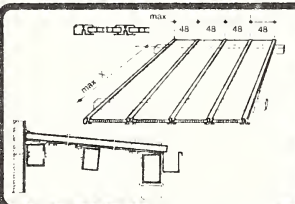
50"	40"	33"	28	60"	45"	38"	33"
1.3 m	1.0 m	0.8 m	0.7 m	1.5 m	1.1 m	1.0 m	0.8 m

ALU PROFILSET (APS 16)



50"	40"	33"	28	60"	45"	38"	33"
1.3 m	1.0 m	0.8 m	0.7 m	1.5 m	1.1 m	1.0 m	0.8 m

PVC-AL 16 PVC-ALE 16



50"	40"	33"	28	60"	45"	38"	33"
1.3 m	1.0 m	0.8 m	0.7 m	1.5 m	1.1 m	1.0 m	0.8 m

ROOF PITCH MIN 5° BETTER 10°

DIAGRAM # 1005

IMPORTANT NOTES ON INSTALLATION

Advice

Ask if you have any questions. The Market Development groups at CY / RO Industries and Chemacryl Plastics Limited are prepared to help you with your application. DO NOT assume something; if you are uncertain - ASK.

Application Safety

SDP double skinned sheets have been used in a wide variety of applications throughout the United States, Canada and Europe. Each locality has Building Codes which regulate methods of construction and the use of building materials, with requirements varying according to location, size of building and type of occupancy. Since regulations vary in different areas, it is always advisable to check local Building Codes. Special applications for SDP double skinned sheet that do not comply with a local Building Code can be evaluated by CY / RO Industries. If the application proves to be a proper and safe use of the material we will be glad to offer assistance in presenting data to help you secure acceptance by local Boards.

Cleaning

SDP double skinned sheet can be washed with mild soap or detergent and water. Change water often so that dirt particles do not scratch the panels. Rinse well with clear, warm water and dry with a soft cloth where applicable.

DO NOT use window cleaning sprays, cleaning fluids or kitchen scouring compounds. DO NOT use solvents such as acetone, chlorinated solvents, lacquer thinner, etc. DO NOT use any substance which contains an abrasive. DO NOT use razor blades or other sharp objects to remove spots.

Cutting

Mark for cutting with a felt tip marker or grease pencil on polyethylene masking. DO NOT mark with a scribe or other sharp instrument.

A special plastic cutting blade works best but hollow ground blades 8" or 10" in diameter designed for sawing brass, copper or aluminum with 6 to 8 teeth per inch are suitable. Recommended thickness of blades = $\frac{1}{16}$ " or $\frac{3}{32}$ ". Teeth should be ground to a uniform height, with 0° rake. DO NOT work with a dull saw, or one that has large raker teeth.

Chips left in the channels after cutting should be vacuumed or blown out using compressed air.

Ends

Make sure that the upper end of each SDP double skinned sheet is closed before installation. (The tape or PEG strip installed by the factory is satisfactory for this purpose). Remove the tape or PEG from the bottom end and close with a CY / RO aluminum terminal section (ATS - Section 4F).

DO NOT seal the SDP double skinned sheet at both ends. Each panel should be "weeped" at the bottom to allow any moisture to drain that might accumulate.

Expansion and Contraction

SDP double skinned sheet expands and contracts considerably more than glass, and provision must be made in the framing system for this amount of movement. The amount of movement can be calculated by:

Temperature 40×10^{-6} in./in./°F.

Humidity 50×10^{-6} in./in./% RH

For example, if the difference in temperature is 100°F. (38°C.) from winter night to full noontime sun—the length of a 10 foot (120") panel of SDP double skinned sheet would change almost a half inch.

Factor		Length of Panel		Temperature Difference
	x		x	
$\Delta L = .0004''$		120''		100°F = .48''

SDP double skinned sheet used in a greenhouse application, where inside temperature and humidity are generally higher than the outside, would tend to bow inward because the interior skin would be expanded slightly in relation to the exterior skin.

We emphasize this point because the amount of movement in the SDP double skinned sheet is the one area which must be fully understood in order to design a trouble-free job.

Fastening

Use a perimeter framing system to enclose all four sides of SDP double skinned panels. A perimeter clamping bar exerts equal pressure but still allows the sheet to expand and contract.

DO NOT fasten SDP double skinned sheet with screws, nails or bolts through the panel (even if the fasteners are gasketed to keep them from touching the plastic).

Flammability

SDP double skinned sheets are produced from molding compounds which are combustible thermoplastics. Precautions used to protect wood and other combustibles from flames and high heat sources should also be observed with these materials. CYROLON SDP polycarbonate sheet will burn when involved in fire but normally extinguishes itself when the flame or fire is removed. ACRYLITE SDP acrylic sheet, however, will burn rapidly to completion if not extinguished. The products of combustion, if sufficient air is present, are carbon dioxide and water. However, in many fires, sufficient air will not be available and toxic carbon monoxide will be formed, as it will from other common combustible materials. We urge good judgment in the end use of these versatile materials and recommend that Building Codes be followed carefully to assure they have been used properly. Access panels may be required for evacuation and venting rooms glazed with SDP sheet. These products burn more rapidly than their solid polycarbonate or acrylic sheet counterparts. Noncombustible end caps must be used to prevent flame from contacting the open ends of SDP sheet. Additional data is available from both CYRO Industries and Chemacryl Plastics Limited.

Framing Systems Rabbit Channel Depth

Provide for plenty of movement in SDP double skinned sheet. Three fourths of an inch is a sufficient bite for most applications.

DO NOT expect that a system designed for glass will automatically work properly for SDP double skinned sheets without checking first with your authorized local fabricator, CY/RO Industries, or Chemacryl Plastics Limited.

Installation

Under certain circumstances moisture accumulation may occur within the ribs. Therefore, SDP Sheet should always be installed with the ribs running vertically. Peel back the polyethylene masking about 1½" from all sides. Install with masking facing outward. Immediately after clamping in place, remove the masking.

DO NOT INSTALL SDP SHEET IN A COMPLETELY HORIZONTAL PLANE. A minimum slope of 6° (1:15) is needed.

Paints and Preservatives

Take care to insure that paints, penetrating sealers and preservatives are compatible with SDP sheet and that contact surfaces are completely dry before installing SDP double skinned sheet.

DO NOT let the panels come in contact with solvents or solvent vapors. These may be harmful and should be avoided.

Sealants

Use the recommended gasketing materials only. You will find our recommendations in Section 3, or ask us about the use of a particular material.

DO NOT assume that the gaskets or caulking material you have on hand will be appropriate for use. Some gasketing materials have plasticizers which are not compatible with acrylic or polycarbonate plastics. Use of such a plasticized material can cause stress cracking, leakage or other potential failure. Compatibility tests should be run on all unknown materials.

Sealing

Use gasketed systems. Sealing corners and joints with silicone generally is a good practice.

DO NOT use sealants that are not recommended.

Storage

Store SDP double skinned sheet in the shade and out of the rain. Vertical storage is preferable so that other items will not be stored on top of the panels. If horizontal storage is required, do not place heavy objects on top.

DO NOT store panels in the direct sunlight. Direct sun can "bake" the masking, making removal difficult. Heavy objects stored on SDP double skinned sheet can cause damage.

Structural Considerations

SDP double skinned sheet is quite rigid, but it is not in itself a structural material. Indeed, its rigidity is a major advantage in glazing large areas. With proper framing and supporting systems, it is capable of taking considerable loads, both positive and negative. If using SDP sheets full-width (47 1/4") with mullions spaced on four foot centers, the recommended maximum distance between purlins is dependent on assigned loading (lbs. per square foot). (Refer to Purlin Distance Chart Diagrams #1004-1005). The purlins are installed at right angles to the glazing bars and from 3/16 to 3/4 inch below the SDP double skinned sheet. Under live load, the panels will deflect to rest on the purlins, transferring the load to them.

Supporting Structure

Follow the recommendations concerning the distance between supporting members, as shown on the chart in the technical section.

DO NOT assume that SDP double skinned panels alone will take the weight of snow without the proper supporting framework.

System Design

If you desire an alternative glazing system, the use of light colored clamping bars to hold down the panels is preferred.

DO NOT use dark colored clamping bars or dark colored purlins because they will absorb sunlight and can cause localized temperature related stress extremes in the panels.

Weeping

Each SDP double skinned sheet and its framing system should be weeped to prevent any buildup of condensation or infiltrated water in the panels of the glazing system.

DO NOT neglect to follow proper weeping techniques or you may suffer an accumulation of moisture or condensation.

CY/RO GLAZING SYSTEMS

4.

Glazing Systems

There are three standard glazing systems designed for SDP double skinned sheets available from CY/RO Industries and Chemacryl Plastics Limited.

APS-16 Aluminum Glazing System

The APS-16 system consisting of a limited number of components was designed primarily for vertical glazing, although it works well for sloped applications.

PVC/Aluminum Glazing System

The PVC/AL and PVC/ALE systems were designed for less demanding applications such as greenhouses and patio covers.

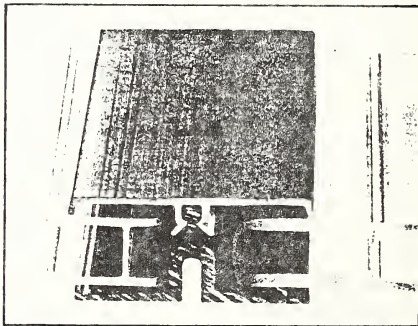
Universal Glazing System

The UGS universal system can be used for a wide variety of applications.

APS-16



PVC/AL



UGS



B. PVC/ALUMINUM GLAZING SYSTEM

The PVC/Aluminum (PVC/AL) and PVC/ALE systems were designed for less demanding greenhouse and small area glazing (such as veranda roof sides, sun decks and patio covers). Consisting of a white, rigid polyvinyl chloride (PVC) snap-on cap and two aluminum glazing bars, the AL-16 regular bar and the ALE-16 end bar can be attached to most super-structures with connecting angles and fasteners.

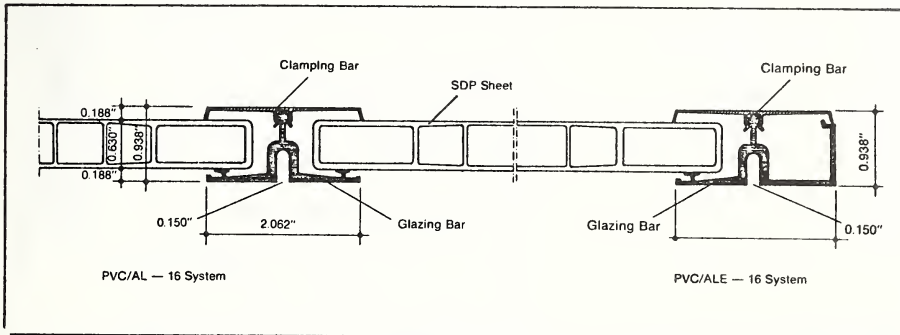


DIAGRAM #1016

The PVC and aluminum system can be used in conjunction with the APS-16 system as shown in Diagram #1016. A connecting angle is fastened with stainless steel self-tapping screws. Any condensation which may form on the underside of SDP sheet is channelled to the exterior at the eave or sill.

Supplied in standard lengths of clamping and glazing bars. Other lengths, and the connecting angles and screws, can be supplied by special agreement.

TECHNICAL DATA

Glazing bar

Material	Aluminum
Weight AL	.367 lb./ft.
ALE	.427 lb./ft.
Alloy and temper	6063-T5
Tensile strength	22,000 psi
Surface	Mill finish, not anodized
Standard length	25'0", other lengths on request

System

Mullion spacing with full-width SDP sheet	48"
---	-----

For roof glazing applications transverse purlins are required at intervals (refer to Purlin Distance Chart Diagram # 1004) to support the SDP glazing panels. Depending upon the snow load design criteria, these purlins may be at spacings ranging from 60" to less than 24". The glazing system must then perform two functions: 1) hold down the SDP double skinned sheets during negative wind loads (wind suction) and 2) ensure a watertight joint between the SDP panels. The AL-16 glazing bars have condensation channels which lead off any condensation or water infiltration that might occur.

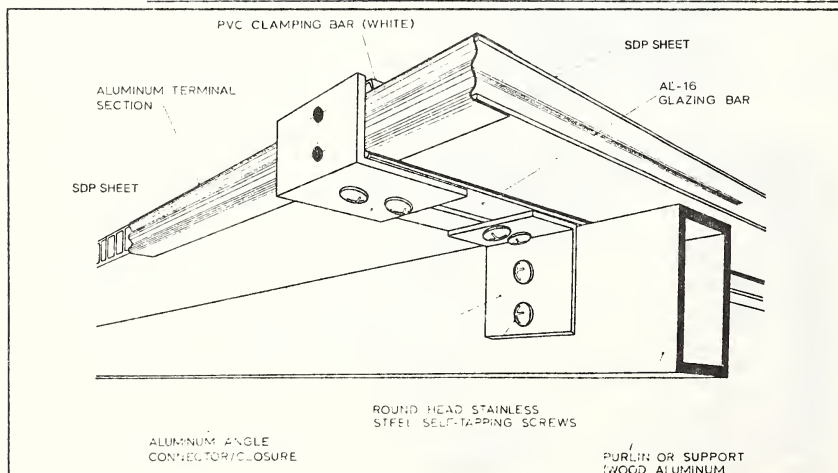
The installation of the aluminum glazing bar differs with the type of materials used in the superstructure. (Refer to Diagrams # 1017 and # 1018 on following pages.) A screw channel for # 10 self-tapping screws eliminates drilling holes into the glazing bars. Connecting angles or clips can also be used to attach the glazing bar to various structural shapes and materials.

The PVC-AL 16 glazing bar can be used as perimeter mullions provided adequate clamping action is maintained. Keep in mind that the SDP sheet lengthens with a rise in temperature, and contracts with a decrease in temperature which may cause motion or movement that may be heard. When used as an eave or sill member, weep holes are required to channel moisture to the exterior. (See Diagram # 1017).

The PVC/Aluminum Glazing System (PVC/AL) can be used for both frames and mullions.

Vertical strip windows, 4 feet or less in height can be economically glazed with SDP double skinned sheets using the PVC/AL system (refer to Diagram # 1018).

However, using the APS-16 system, mentioned previously, for framing and the PVC/AL system for mullions is often a more satisfactory method (refer to Diagram # 1021). Once the glazing bar is attached to the purlin superstructure, the SDP sheet is put into place between the aluminum glazing bars and held down with the PVC cap. The PVC cap is grooved so that it snaps down over the "tongue" of the glazing bar. To facilitate installation of the cap, bend the PVC strip slightly away from the glazing bar to "open up" the groove. Then tap the strip along the glazing bar with a plastic or rubber mallet to insure a tight grip. Note that no gaskets or liquid sealants are used with the PVC/AL system except as required to seal the PVC cap junctions, or to seal the glazing bar at the building.

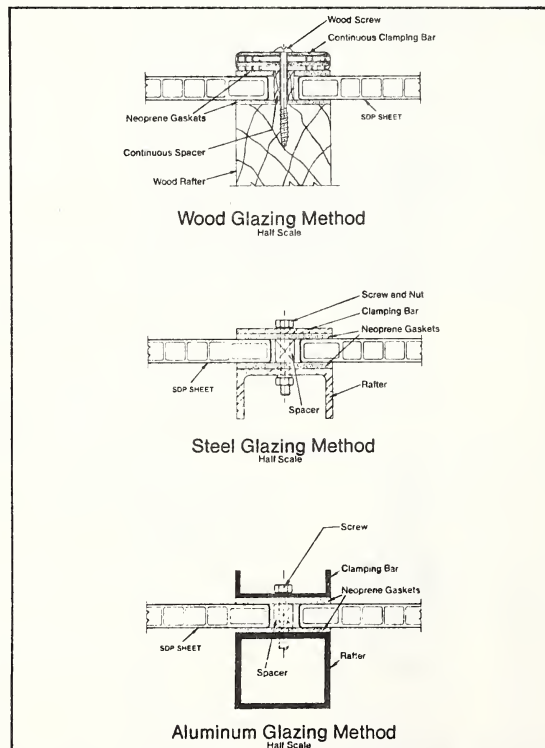


E. ALTERNATE GLAZING METHODS

The glazing systems offered by CY /RO Industries and Chemacryl Plastics Limited are designed specifically for use with SDP double skinned sheets. There are other systems available, but these are usually designed for glass. With some precautions (glazing channel depth, compatibility of gaskets and sealants, etc.) SDP sheets can be used as glazing panels in these alternate systems. (See Section 2.)

In some applications sophisticated glazing members are not required. The end-user may wish to use standard structural members, such as laminated wood, steel, or aluminum which are available from local building supply companies. The necessary EPDM gaskets can be bought from most local rubber supply firms. The continuous spacer (see Diagram # 1007) ensures that the clamping bar will exert equal pressure on the SDP sheet. Otherwise, the fasteners—spaced at 9" to 12" centers—could impart localized stressing at points of attachment. The SDP sheet would then be restricted from expanding and contracting over the total length of the sheet.

The Universal Glazing System—UGS—(refer to Section 4D) can be substituted as the clamping bar and gaskets of any of the alternate glazing methods shown. Sourcing these components would then be eliminated, as both the gaskets and the clamping bar are available from CY/RO Industries and Chemacryl Plastics Limited.



F. ALUMINUM TERMINAL SECTION (ATS)

4F

Glazing Systems

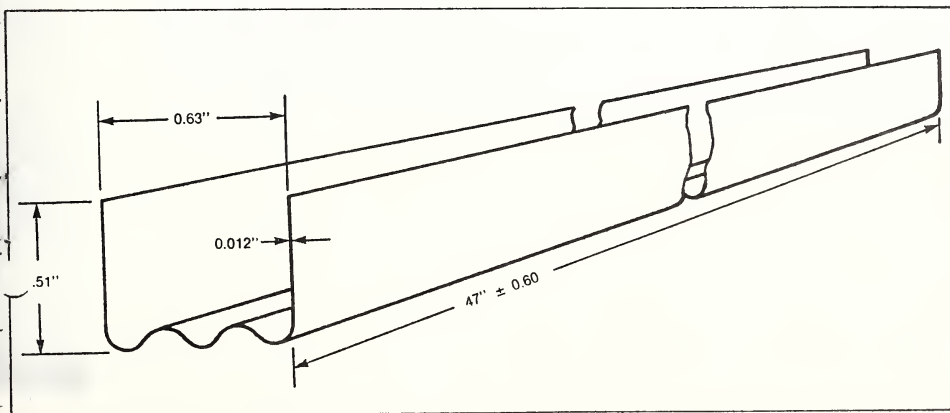
The aluminum terminal section (ATS) is used as a sealing element to close the ends of the SDP acrylic and polycarbonate sheets. It should substantially prevent the entry of drafts, dust and rainwater into the chambers of SDP sheet and permit, at the same time, the drainage of condensed water which may possibly form in extreme cases. It protects the ends of SDP sheet against mechanical stress and diminishes the possibility of sheet ignition from flame.

TECHNICAL DATA

Material	Stove enamelled aluminum sheet
Section	Channel section with water drainage grooves
Length	$47'' \pm 0.06''$
Height of side	0.51''
Sheet thickness	0.012''
Weight	Approx. 1.5 oz. each
Color	White outside

The sealing section is most useful for warm and humid buildings glazed with SDP sheet. Here the sheets should always be fitted in such a way that the webs are vertical or at a steep incline. The sealing section can be used for the lower closure of vertical or roof glazing when SDP sheet is supported at the bottom and for freestanding, upper ends. It must be remembered that the sealing section is liable to be pushed off when there are great changes in length combined with wedge attachment at the ends of SDP sheet. If so, the section may have to be additionally bonded with silicone sealant.

The simplest method of assembly is to slip the sealing section from the side over the end of the sheet without letting it buckle.



4F-1

G. Polyethylene Gasket System (PEG)

The 47 1/4" long PEG (polyethylene gasket) strip (Diagram #1030) was designed to fit in between the internal ribs at both ends of the SDP sheets to protect the panels during shipment.

The flexible protrusions of the PEG strips allow it to be attached to the open channel ends of the sheets.

When SDP sheets are installed the lower PEG is removed and replaced by the ATS. The PEG in the upper edge remains in place.

Available from both CY /RO Industries and Chemacryl Plastics Limited, the polyethylene strip is supplied in bundles of 32 pieces.

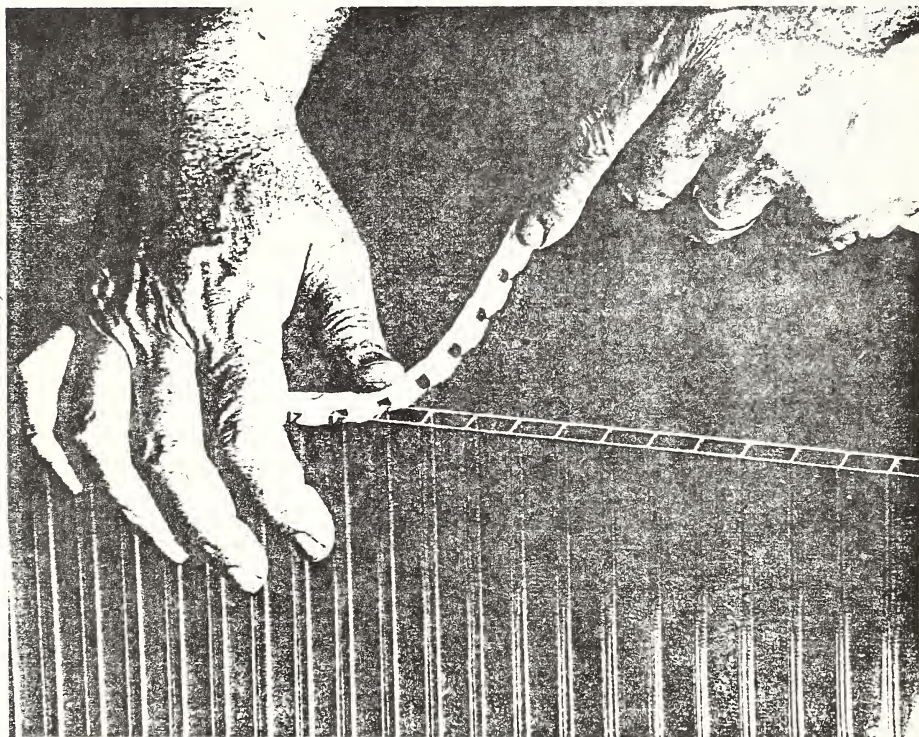


DIAGRAM # 1030

APPENDIX 2

Vent Actuator System Design

Calculating Mounting Dimensions

I. Definition of Piston Dimensions

L_{min} = the compressed length of the air shock measured between mounting centers plus .5 inch to reduce bottoming out.

L_{max} = the expanded length of the air shock minus .5 inch to reduce top limiting.

r = largest radius of air shock (measure largest circumference and divide by 2π).



II Simplified Diagrams

On each of the simplified diagrams note that all measurements are made from the center of the hinge pin along lines parallel or perpendicular to the wall or panel. Be sure to add any extra distances, such as $\frac{1}{2}$ the thickness of the hinge to the calculated values.

A. Lower Piston on Vertically mounted panel.

A, B, D, E as shown.

1. if you choose $A = E$, $D = r$

then

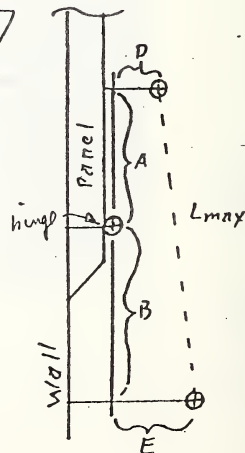
$$B = r + L_{min}$$

$$A = \frac{-L_{min} + \sqrt{L_{min}^2 - 2(L_{min}^2 + 2rL_{min} + 2r^2 - L_{max}^2)}}{2}$$

2. if you choose $E = D = r$

$$A = \frac{L_{max} - \sqrt{4rL_{max} - 4r^2 - L_{max}^2 + 2L_{min}^2}}{2}$$

$$B = L_{max} - A$$



3. if you are given values for $E \& D$ ($E=E_1, D=D_1$) then you must solve

$$\begin{cases} 0 = (A + D_1 + \sqrt{L_{min}^2 + (A - E_1)^2})^2 + (E_1 - D_1)^2 - L_{max}^2 \\ 0 = (A + B)^2 + (E_1 - D_1)^2 - L_{max}^2 \end{cases}$$

for $A \& B$ by iterative procedures.

B. Green house Vent mounted on rafter.

Let θ be the maximum opening angle of the vent
 δ be the slope of the roof.

A, D, S, T, R, V as shown.

then:

$$S = \frac{D + \sqrt{L_{min}^2 (1 + \tan^2 \delta) - D^2 \tan^2 \delta}}{(1 + \tan^2 \delta)}$$

$$A = \frac{-(KP + MN) + \sqrt{(KP + MN)^2 - (K^2 + M^2)(P^2 + N^2 - L_{max}^2)}}{K^2 + M^2}$$

Where:

$$\begin{aligned} K &= (\sin \delta + \sin(\theta - \delta)) \\ P &= \left(\frac{\delta}{\cos \delta} - D \cos(\theta - \delta) \right) \\ M &= (\cos(\theta - \delta) - \cos \delta) \\ N &= (D \sin(\theta - \delta)) \end{aligned}$$

$$T = A + S \tan \delta$$

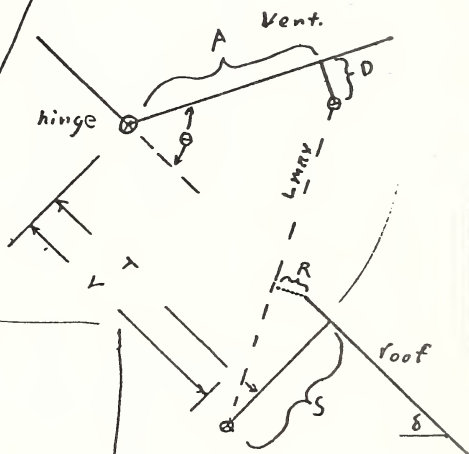
to test for clearance

$$R = (\sqrt{(V - T)^2 + S^2}) \sin(\delta + e - \pi)$$

where:

$$e = \tan^{-1} \frac{D}{A}$$

$$\pi = \tan^{-1} \left(\frac{A \cos e + D \cos e - T \cos \delta + S \sin \delta}{T \sin \delta + S \cos \delta} \right)$$



PROGRAMMER

DATE

Coding Form



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TEXAS INSTRUMENTS
INCORPORATED

TITLE _____ PAGE _____ OF _____

TI Programmable
Coding Form

PROGRAMMER _____ DATE _____

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SFD CODES

BED CODES

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TEXAS INSTRUMENTS
INCORPORATED

TI-241B1

PROGRAM DESCRIPTION

Math on attached sheets.

USER INSTRUCTIONS

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22.5	LX		22.5	LX		22.5		LX	
60.	AG		80.	AG		45.		AG	
8.75	C		8.75	C		8.75		C	
1.	SL		1.	SL		1.		SL	
9.162	A		6.925	A		12.224		A	
10.266	S		10.266	S		10.266		S	
19.428	T		17.192	T		22.490		T	
9.072	R		10.942	R		6.446		R	
6.234	F		6.400	F		6.033		F	

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C		Z 2	R		Z 32			☐ EE	☐ I	☐ J	☐ +	☐ CTO	☐ X										
D		Z 3	(KP→MIN)		Z 33			☐ SUB	X ☐	☐ RST	☐ *	☐ RS	☐ -										
E		Z 4	T		Z 34			☐ +/-	☐ =	☐ CLF	☐ INV	☐ UP	☐ DP										
A'		Z 5	F		Z 35			☐ CM	☐ W	☐ S+I	☐ SD	☐ CES	☐ CS										
B'		Z 6	E		Z 36			☐ LAR	☐ PR	☐ LRI	☐ LAR	☐ LR	☐ LD										
C'		Z 7	H		Z 37			☐ LRF	☐ TMT	☐ X+1	☐ LMP	☐ LRS	☐ DR										
D'		Z 8	V-T		Z 38			☐ HLL	☐ X+1	☐ ZC	☐ ZR	☐ GRP	☐ ULR										
E'		Z 9			Z 39			☐ SHL	☐ RMS	☐ ZP	☐ LSI	☐ SHR	☐ DLR										
								☐ HIR	☐ ZAL	X													
FLAGS		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15						

II Solve for S

$$L_{min}^2 = S^2 \tan^2 \delta + S^2 - 2DS + D^2$$

$$0 = S^2 (\tan^2 \delta + 1) - 2DS + (D^2 - L_{min}^2)$$

$$S = \frac{+2D \pm \sqrt{4D^2 - 4(\tan^2 \delta + 1)(D^2 - L_{min}^2)}}{2(\tan^2 \delta + 1)}$$

Assume + Bechuge $S > D$

$$S = \frac{D + \sqrt{D^2 - (\tan^2 \delta + 1)(D^2 - L_{min}^2)}}{(\tan^2 \delta + 1)}$$

$$S = \frac{D + \sqrt{D^2 - D^2 \tan^2 \delta - D^2 + L_{min}^2 \tan^2 \delta + L_{min}^2}}{(\tan^2 \delta + 1)}$$

$$S = \frac{D + \sqrt{L_{min}^2 (1 + \tan^2 \delta) - D^2 \tan^2 \delta}}{(1 + \tan^2 \delta)}$$

III Solve A, S Known

$$L_{max}^2 = \left[A \overbrace{(\sin \delta + \sin(\theta - \delta))}^K + \overbrace{\left(\frac{S}{\cos \delta} - D \cos(\theta - \delta) \right)}^P \right]^2 + \left[A \overbrace{(\cos(\theta - \delta) - \cos \delta)}^M + D \overbrace{\sin(\theta - \delta)}^N \right]^2$$

$$L_{max}^2 = (KA + P)^2 + (MA + N)^2$$

$$L_{max}^2 = K^2 A^2 + 2KPA + P^2 + M^2 A^2 + 2MNA + N^2$$

$$0 = (K^2 + M^2)A + 2(KP + MN)A + (P^2 + N^2 - L_{max}^2)$$

$$A = \frac{-2(KP + MN) \pm \sqrt{4(KP + MN)^2 - 4(K^2 + M^2)(P^2 + N^2 - L_{max}^2)}}{2(K^2 + M^2)}$$

$$A = \frac{-(KP + MN) + \sqrt{(KP + MN)^2 - (K^2 + M^2)(P^2 + N^2 - L_{max}^2)}}{(K^2 + M^2)}$$

IV Location of splices from Hing

$$T = A + S \cos \delta$$

V Clearance from foot at max.

$$E = \tan^{-1} \frac{P}{A}$$

$$\Pi = \tan^{-1} \left(\frac{A \cos E + D \sin E - (T \cos \delta - S \sin \delta)}{T \sin \delta + S \cos \delta} \right)$$

$$\Pi = \tan^{-1} \left(\frac{A \cos E + D \cos E - T \cos \delta + S \sin \delta}{T \sin \delta + S \cos \delta} \right)$$

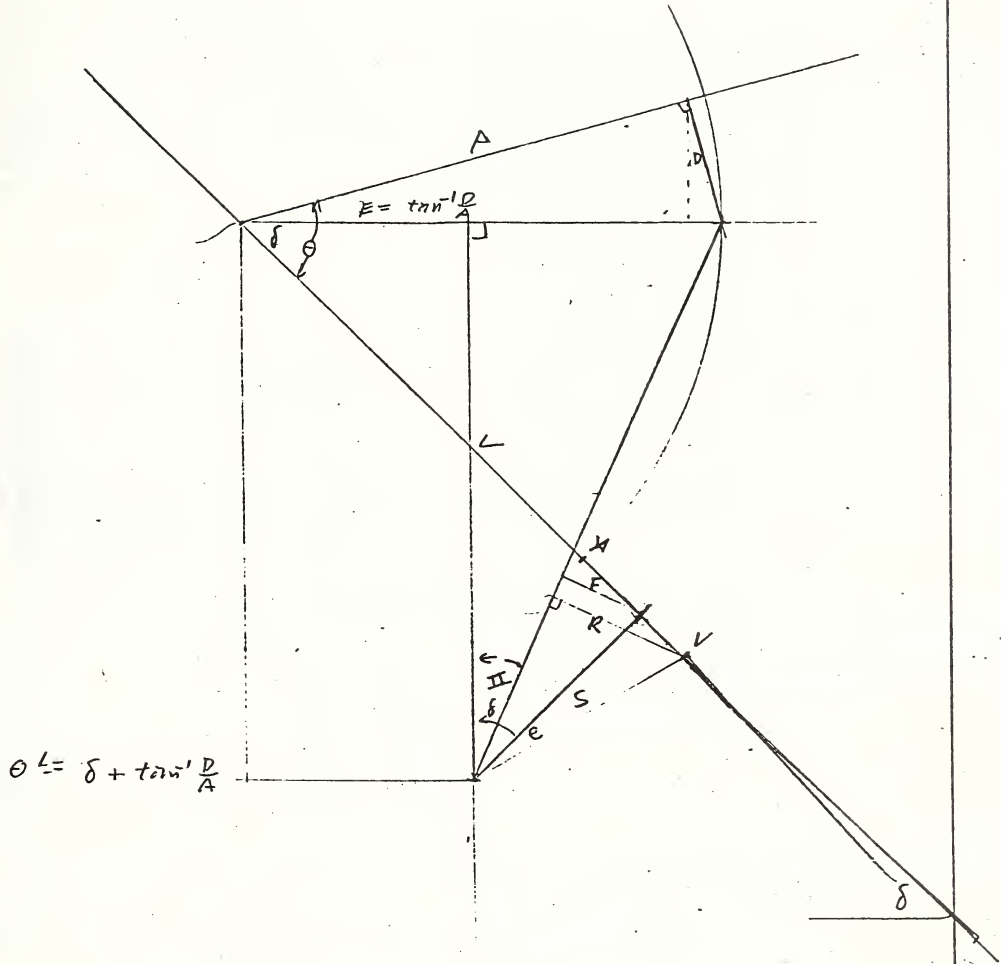
$$F = S \sin (\delta - \Pi)$$

VI R

$$e = \tan^{-1} \left(\frac{V - T}{S} \right)$$

$$R = \left(\sqrt{(V - T)^2 + S^2} \right) \sin (\delta - \Pi + e)$$

Clearance

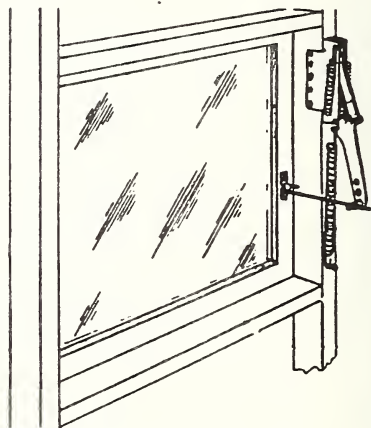
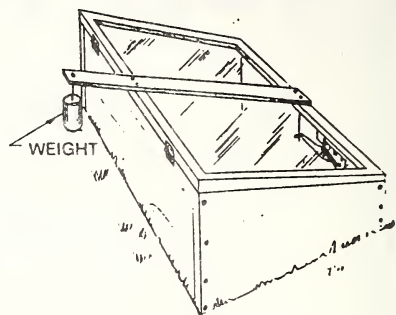


SOLARVENT™

Solar Powered, Fully Automatic Green House Window Ventilator

The SolarVent automatic vent is used to open a ventilating window to prevent excessive heat buildup. It will open a standard 2 foot square double strength glass, aluminum framed window approximately 7-1/2 inches. It opens automatically as the temperature changes from 65°F (18°C) to 75°F (24°C) and closes when the temperature falls. This easy-to-install, fully automatic ventilating unit is operated by a heat sensitive expanding chemical. This ventilator can be used on any ventilating window which does not exceed nine (9) pounds.

SolarVent requires no electric power and installs in minutes to either aluminum or wooden frames. All mounting accessories are included. This unit has a variety of applications and is adaptable for use as a greenhouse ventilator, an automatic vent for a trombe wall solar collector or an automatic register regulator for individual room heating control, using the entire unit or just the power pack and adapting the system you need.



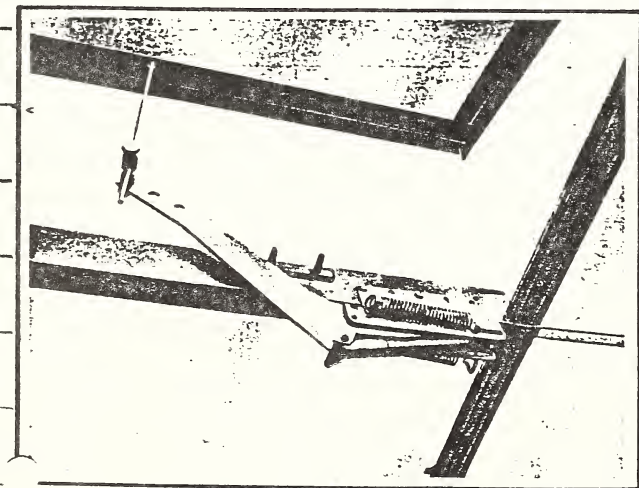
Complete unit as pictured

CAT.No. 103P-1 1 LB. \$24.95

Counter Balance Spring Assembly
(Increases lifting capacity from
9 lbs to 20 lbs - not pictured)

CAT.No. 103P-2 ½ LB. \$2.98

Power Pack (solar activated chemical
power pack for custom installations.) See page 199 for options.



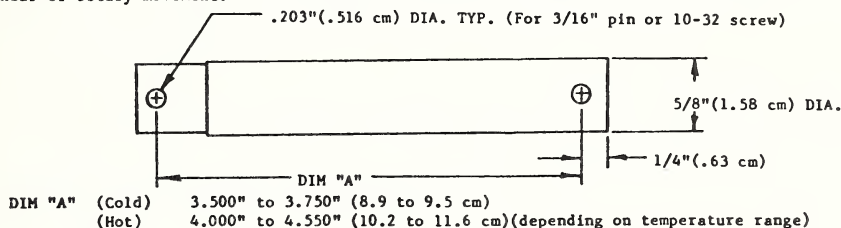


dalén products, inc.



THERMAL OPERATOR

The Dalen Series 35 operator is a self-contained power unit which extends its length in response to rising temperature and can be used to perform various tasks, such as: opening and closing ventilators and shutters, raising and lowering curtains, opening and closing valves, etc. It is a simple, inexpensive, foolproof device which has proven over many years to be extremely dependable over tens of thousands of cycles. It can be used in air, water, antifreeze, and many other mediums. It is not effected by extremes of weather or temperature. It is constructed of stainless steel, brass and copper for excellent corrosion resistance. It has no moving seals to leak or wear out. It works using a confined chemical which expands when it melts at a predetermined temperature. This stretches a diaphragm which moves a stem to perform the work. It mounts easily to any custom installation for linear or rotary movement.



SPECIFICATIONS:

STROKE: .400" to .800" (1 to 2 cm)
 MAXIMUM LOAD: 35 pounds (16 kg)
 MINIMUM LOAD: 10 pounds (4.5 kg) (required for return to cold position)
 EXPECTED LIFE: In excess of 20,000 cycles (can be much higher depending on conditions)
 OVERTEMPERATURE LIMIT: 250°F (120°C)
 TEMPERATURE RANGES: This unit can be manufactured for almost any range between 60°F (15°C) and 250°F (120°C). However, samples and low quantities must be limited to stocked ranges. Ranges which are commonly available are listed below:

Model No.	Starting Temp.		Full Stroke Temp.		Min. Stroke	
	°C	°F	°F	°C	IN	CM
35-62	16-18	60-64	68	20	.750	1.9
35-68*	17-20	65-68	75	24	.750	1.9
35-105	37-41	102-107	129	54	.520	1.32
35-120	46-50	115-122	150	65	.520	1.32
35-142	59-63	138-145	170	77	.460	1.17
35-160	68-72	155-162	182	83	.520	1.32
35-170	75-79	167-174	192	89	.520	1.32
35-180	79-83	175-182	202	94	.520	1.32
35-192	87-90	188-195	212	100	.520	1.32
35-195	89-93	192-199	219	104	.520	1.32

NOTE: In most cases, operator will exhibit a 4°F (2°C) hysteresis between expansion and contraction.

COMBINING RANGES: Series 35 operator contains two thermal elements so that two ranges can be combined by using one element of each range (e.g. one element each from 35-160 and 35-180 would result in a stroke of .520" from 155-162°F to 202°F).

* The 35-68 is a standard model available from stock. All others require a stock confirmation prior to order. Usually a high temperature model is available. (Solar collector over temp. control)

CAT.No. 103P-3	MODEL 35-68	SHPG.WT. 1 LB	\$14.95
CAT.No. 103P-4**	OTHER MODELS	SHPG.WT. 1 LB	24.95

**NOTE: STATE MODEL NO. IN DESCRIPTION COL. OF ORDER BLANK

APPENDIX 3

Floor Construction Method: An Analysis

July 19, 1978

REQUEST FOR CHANGE IN FLOOR CONSTRUCTION METHOD: AN ANALYSIS

Investigation of the cost of materials, and further thermal analysis occurring since the time of submission of my application indicate that the floor of the greenhouse is cost ineffective as designed in the application, and that it can be improved from a thermal standpoint. As a result, I would like to change the construction of the floor from the proposed heavyweight concrete blocks (uninsulated), to a poured-in-place concrete slab over rigid insulation.

The original reason for going to the set-in-place blocks in the application was partially aesthetic; (there could be a pattern introduced by the joints in the block, instead of a large, unbroken slab), and partially practical; (if it ever became necessary to run water lines or electrical conduit through the greenhouse, I could simply remove some blocks, install the lines, and replace the blocks). A slab on the other hand, would have to be jackhammered to enable the installation of any lines once the concrete had been poured.

The problem occurs when one considers the cost of using the concrete blocks on a square foot basis. Contact with Mr. Leonard Bogut* of the Havre Block Company (the only supplier for these heavyweight blocks in Montana) indicates the units would cost \$.63 apiece, which is 71¢ per square foot, but other charges considerably inflate the charge from there.

Cost Per Square Foot Of Floor Using Heavyweight Blocks:

810 blocks (4"x8"x16") @63¢ apiece	\$510.30
Transportation from Havre to Butte	250.00
Pallets - seven @ \$6.00 apiece	42.00
Hyster rental for unloading in Butte	50.00
	<u>\$852.30</u>

This cost, averaged over 720 square feet, works out to \$1.18 per square foot, and makes no allowance for heat escaping from the greenhouse through the floor.

I believe that I have achieved a better design, which combines the aesthetics of a block floor with the economics of an all-slab floor and yet is completely insulated below the floor for better heat retention in the greenhouse, and at a savings of nearly one-third.

The alternate design I am proposing consists essentially of casting the floor of concrete in sections; (which is not only easier to do than pouring and finishing the entire floor at once, but is considerably easier than hand-setting 810 blocks weighing 32.5 pounds apiece!). The sections, each about eight feet by twelve feet, would be cast in place leaving a sixteen inch wide space between them. Then, used brick pavers would be set in the strips between the slabs on a sand bed and flush with the top of the slab. The entire floor would be set on a two inch thick layer of rigid "beadboard" insulation, using polyethylene moisture barriers to prevent deterioration of the beadboard's insulative value. The resultant floor would be quite attractive, and removal and reinstallation of the pavers to facilitate utility lines would be a snap. A cost analysis of this arrangement is as follows:

Cost Per Square Foot Of Floor Using Concrete Slab And Old Brick :

Five cubic yards concrete @ \$40.00 each	\$200.00
720 sq. ft. wire mesh reinforcing @ 7¢/sf.	50.50
1170 used brick pavers @ 10¢ apiece	117.00
720 sq. ft. 2" beadboard rigid insul @ 32.5¢/sf	234.00
	<u>\$601.50</u>

This cost, averaged over 720 square feet, works out to \$.84 per square foot, including the insulation.

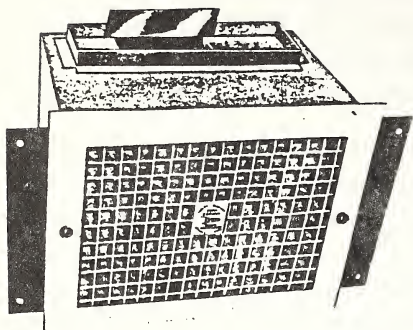
NOTE

In requesting the above change in construction method, I only anticipate receiving from the Department of Natural Resources the \$ 526.50 contained in the budget for the floor as originally proposed. I agree to provide the additional cost of the floor above this amount, (ie. \$75 or so). While this is less by \$25.00 than the amount I had shown as provided by me for shipping and delivery costs for the heavyweight concrete blocks, I still anticipate contributing at least \$ 1,229.35 to the total project before it is completed. For the sake of simplicity I have included the cost of the alternate floor as a lump sum in the cost breakdown portion of the Advance Request attached. I trust that the Grantor will allow this change for the reasons I have outlined above.


Robert J. Corbett-Grantee

APPENDIX 4

Manufacturers' Literature:
Fan and Controller



**THE WORLD'S
QUIETEST
CEILING, CABINET
AND
IN-LINE FANS**

THE RENOWNED PENN

ZEPHYR



PEAN VENTILATOR GEARING

[illegible]

ARE MOVING SPECIALISTS FOR OVER 50 YEARS

Engineered by Penn Ventilator Co., Inc., the Penn ZEPHYR is the first ceiling fan with its own built-in muffler. A well chosen combination of high quality components and acoustical insulation make the ZEPHYR the only completely quiet ceiling mounted exhauster. The ZEPHYR was tested in Penn Ventilator Co's AMCA approved laboratory rated across the entire static pressure spectrum. Air ratings are given in CFM rather than in square feet as is the practice in the residential field. All ZEPHYRS bear the AMCA Certified Ratings Seal. Sound levels were obtained in accordance with Bulletin 300 of the Air Movement & Control Association. These tests revealed that the ZEPHYR developed only a small fraction of the noise inherent in other ceiling fans. Insist on the PENN ZEPHYR—there is none other like it.

THE FACTS

For years, low cost but noisy and undesirable ceiling exhausters have dominated the residential market. Engineers have been forced to use these products on even the best designed industrial, commercial and institutional buildings simply because there was no better alternative. Now PENN has produced that better alternative and below are listed correlated comparisons between competitive units and the PENN ZEPHYR.

FEATURES

- * Six ZEPHYR Models from 125* CFM to 3000 CFM
- * Lower-Than-Ever Sound Ratings
- * Slow Speed, High Quality Ball Bearing Motor
- * Acoustically Insulated Housing
- * True Centrifugal Wheel Design
- * No Metal-to-Metal Contact of Moving Parts
- * UL and CSA Labels on All Ceiling Fan Models
- * Grille of Latest Open Area Egg-Crate Design
- * Chatterproof Backdraft Damper
- * Motor and Fan Removable
- * Accessible Terminal Box
- * Exhaustively Laboratory Tested
- * Job Proven in Countless Installations
- * Certified Ratings Authorized by AMCA

CERTIFIED RATINGS



Authorized by AMCA

Penn Ventilator certifies that the ZEPHYR models shown herein are licensed to bear the AMCA Seal. The ratings shown are based on tests made in accordance with AMCA Standard 210 and comply with the requirements of the AMCA Certified Ratings Program. Performance shown is for ZEPHYR models without ducts. The AMCA Certified Ratings Seal applies to air capacities only.



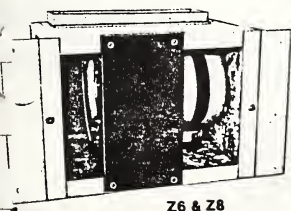
Penn ZEPHYR fans carry the UL label. This is your assurance, not only of electrical reliability, but of conformity of product. UL approval covers the entire unit, not just the electrical components.



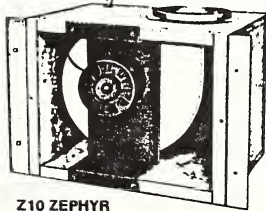
Penn ZEPHYR fans are listed with Canadian Standard Association.

1. Extra quiet operation. The ZEPHYR runs at 1050 RPM or less, with large fan wheel to give air movement at silence levels. Other fans operate up to 3600 RPM.
2. Wide capacity range. From 125 CFM to 3000 CFM (0" S.P.) making it the most versatile ceiling fan available.* The ZEPHYR JR. and ZEPHYRETTE provide lower air volume.
3. Engineered ratings. Fans move air (CFM) not square feet. We tell you exactly how much, at what pressure, speed, horsepower, sound, vibration and magnetic hum level. Moves high volume of air quietly and steadily.
4. Quality construction throughout. From the acoustically insulated muffler box to the damper, face grille, etc., all components are AAA1 quality.
5. Knowledgeable manufacturers. The ZEPHYR is made by Penn Ventilator Co., Inc., the leader in the air moving field for over 50 years.
6. True rubber vibration isolators. The ZEPHYR is the only fan publishing vibration ratings—simply because there is practically no vibration. Motors float in resilient rubber-in-shear.
7. Decorator Deluxe Grille is standard. An attractive molded white ceiling grille enhances the appearance of any room. Open 85% free area aids performance.

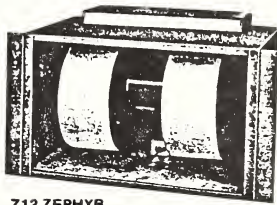
THE HEARTS OF THE ZEPHYR



Z6 & Z8



Z10 ZEPHYR



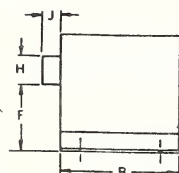
Z12 ZEPHYR

PENN ZEPHYR CEILING FAN

ZEPHYR MODEL NUMBER	VIBRATION ¹ LEVEL (mils)	MAGNETIC ² HUM LEVEL (db)	MOTOR ³ R.P.M.	MOTOR 60 Hz A.C.	MAX. WATTS INPUT	SHIPPING WEIGHT (lbs.)	FAN CAPACITY—CUBIC FEET PER MINUTE ⁴							
							S.P.	0"	.05"	.10"	.125"	.250"	.375"	.500"
Z6	0.25	40	1050	115/1	50	21	CFM	125	110	95	90			
							SONES ⁵	1.7	1.7	1.7	1.6			
Z8	0.38	43	1050	115/1	105	26	CFM	250	230	210	200	145		
							SONES ⁵	2.4	2.4	2.3	2.2	2.1		
Z10	0.42	50	1050	115/1	130	36	CFM	425	405	385	375	320	245	
							SONES ⁵	3.6	3.6	3.5	3.4	3.3	3.1	
Z12	0.48	52	1050	115/1	280	60	CFM	925	905	885	875	805	710	560
							SONES ⁵	4.6 ⁶	4.5	4.4	4.3	4.2	4.0	3.7

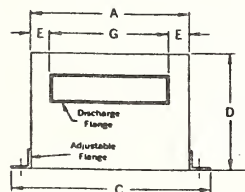
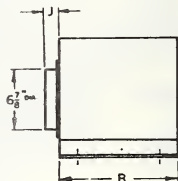
When large capacity units are required, refer to Zephyr Cabinet Fans on pages 6 and 7.

- (1) Vibration amplitude in mils at operating speed.
- (2) Sound pressure level in decibels (re. .0002 Microbars) in the 2nd octave band, 5' 0" from the Zephyr inlet in free space.
- (3) RPM shown is nominal and the performance is based on actual speed of test.
- (4) Sone ratings in accordance with AMCA Bulletin 300-67.
- (5) The AMCA Certified Ratings Seal applies to air capacities only.
- (6) Approximately the same sound level as the fan in a small room air conditioner. Use Lek-Trol LT50 speed control to regulate air flow and noise level.

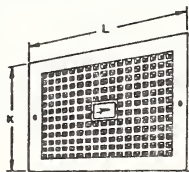


MODEL NO.	A	B	C	D	E	F	G	H	J	K	L
Z6	12½"	9½"	16½"	9"	1½"	5½"	10"	3½"	¾"	11"	13½"
Z8	13½"	11½"	17½"	11½"	1½"	7½"	10"	3½"	¾"	13½"	14½"
Z10	18"	14½"	21½"	14"	13"	7½"	—	—	¾"	15½"	18½"
Z12	23½"	14½"	27½"	14"	21½"	8½"	17½"	5½"	1½"	15½"	24½"

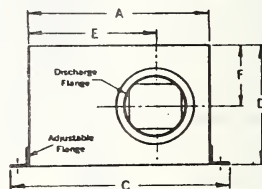
All dimensions are in inches.



ZEPHYR MODELS Z6, Z8, & Z12



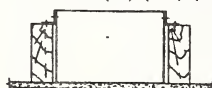
ZEPHYR GRILLE



ZEPHYR MODEL Z10

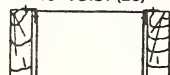
AFTER CEILING IS INSTALLED
WITH ACCESS FROM ABOVE

8" JOIST (Z6)
8" & 10" JOIST (Z8) (Z10) (Z12)



CEILING

10" JOIST (Z6)

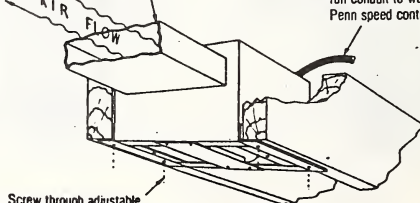


BEFORE CEILING IS INSTALLED

Run to duct system or Penn
accessory roof or wall cap.

Attach appropriate duct
to exhaust duct sleeve.

Install electrical service and
run conduit to wall switch or
Penn speed control.



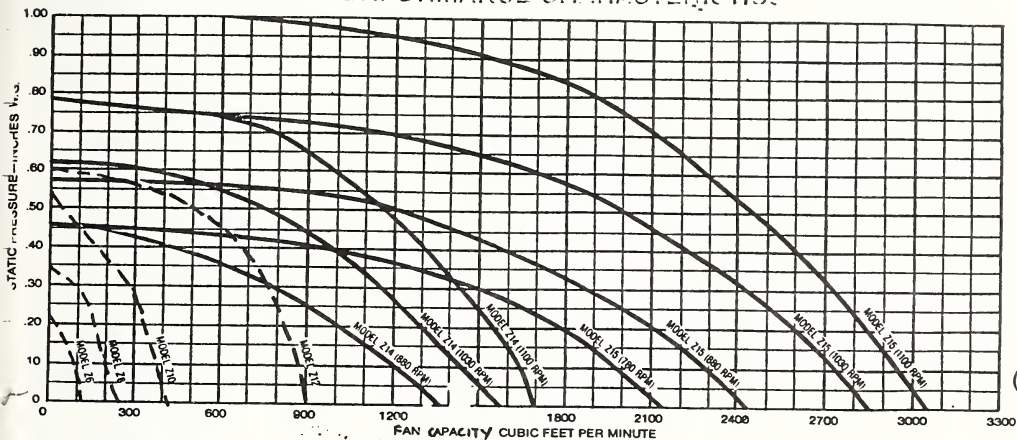
THE LATEST

SONE VALUES lower than ever are available on all ZEPHYR models. This effective overall measure of sound clearly shows the ZEPHYR superiority over all other ceiling fans.

VIBRATION LEVELS are shown for the first time on any ceiling fan. Our new MIRACLE MOUNT rubber-in-shear vibration isolators eliminate practically all vibration. The results are tabulated on page 3 with vibration amplitude (in mils) shown at the actual operating speed.

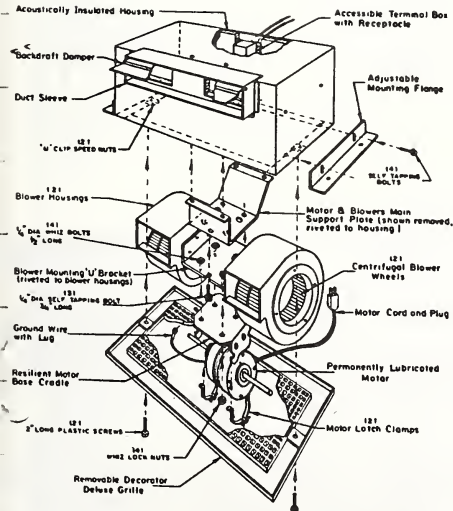
MAGNETIC HUM LEVELS are practically eliminated from all ZEPHYRS. Magnetic hum (also known as 60 cycle hum) is one of the most annoying and yet prevalent fan noises. This is especially true when air noise is reduced. ZEPHYR magnetic hum is tabulated on page 3 in sound pressure decibels for the appropriate octave band at 5' 0" from the fan in free space.

ZEPHYR PERFORMANCE CHARACTERISTICS



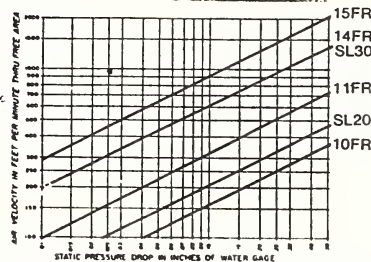
ZEPHYR Z12

EXPLODED VIEW OF TYPICAL COMPONENTS

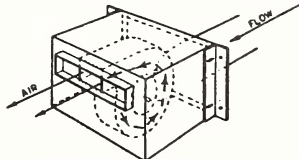


STATIC PRESSURE DROP CHART

For ROOF CAPS



TOP DISCHARGE and IN-LINE MODELS

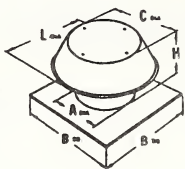


The "TD" (Top Discharge) model is an optional modification of the Zephyr to facilitate wall mounting or direct, in-line mounting. The "TD" Zephyr is furnished without its grille when used as an in-line duct fan (sometimes called a Cabinet Fan) with ductwork leading to and from the Zephyr. Models Z6TD thru Z12TD (add TD suffix to the model of your choice) are available. Access to components can be provided through a removable panel (when ordered) that replaces the face grille.

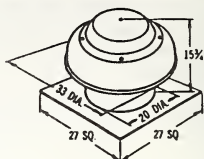
PENN ZEPHYR ACCESSORIES

Efficient Penn Flat Roof Caps are spun aluminum, rustproof, seamless vents which provide the perfect discharge head for flat roof mounting.

They are unobtrusive and furnished with integral bird screen. They are designed for simple, safe flashing directly to the roof.



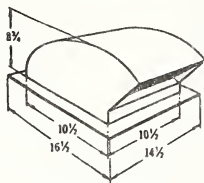
For		A	B	C	H	L
Z6	1 1/2" x 1 1/2"	7 1/2"	12"	9 1/4"	8 3/16"	11"
Z8	1 1/2" x 1 1/2"	12"	19"	12 1/4"	8 3/16"	17 1/2"
Z10	1 1/2" x 1 1/2"	16"	23"	18 1/4"	10 3/16"	22 1/2"



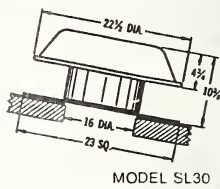
MODEL 15 FR
For Z14 & Z15

SLOPED ROOF CAPS

Minimum height caps are available for sloped roof applications. Model SL20 is available in painted steel and has an extra backdraft damper in addition to the Zephyr damper. Model SL30 is similar to the FRs and is suitable for mounting on slope roofs within a 4" in 12" pitch. For steeper slopes, use 14" Omega (see Engineering Bulletin OM-70) with Adjustable Roof Jack.



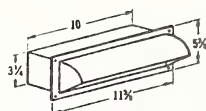
MODEL SL20
For Z6, Z8 & Z10



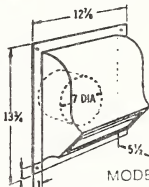
MODEL SL30
For Z12

WALL CAPS

Inconspicuous but efficient wall outlets for the ZEPHYR are provided through the use of the Wall Cap. Architectural values are not diminished by this tastefully designed accessory and when properly installed it is both weather-tight and effective.

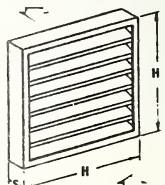


MODEL WC10
For Z6 & Z8



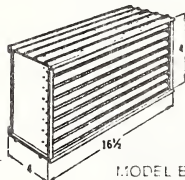
MODEL WC20
For Z10

For	Wall Cap MODEL	H	S
Z12	WC30	24"	2
Z14	WC40	30"	

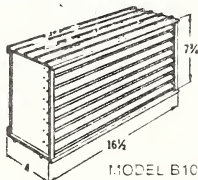


BRICK VENTS

Dimensioned to replace multiples of standard size brick or concrete blocks. Constructed of extruded aluminum sections with insect screen, stormproof features, and a protective finish, make them a superior vent and ideal for installation in masonry walls.



MODEL B65
For Z6 & Z8



MODEL B100
For Z10

For	Brick Vent MODEL	H	S
Z12	B120	24"	2
Z14	B150	30"	

The Lek-Trol variable speed controller permits you to control the ZEPHYR air movement from 100% of capacity down to approximately 50%. The Lek-Trol employs the latest type of solid state "quadrac" circuitry and insures not only complete speed-range control and extra long-life reliability but also a savings in the cost of electricity. This solid state controller is much better suited to this type of fan than conventional speed controllers.

MODEL LT
(2.5 Amps Max.)
For Z6, Z8 & Z10

MODEL LT60
(5 Amps Max.)
For Z12

MODEL LT10
(10 Amps Max.)
For Z14

MODEL LT5
(5 Amps Max.)
For Z15



TIME DELAY SWITCH

The AIRMINDER time delay switch is an inexpensive, single gang, toggle switch and time delay relay that operates both the Zephyr and the room light. The Lek-MINDER AM12 operates any size Zephyr using 120 volt power and ventilates the room even after the occupants leave.

SNAP ON: Light on immediately. Zephyr on within 15 seconds.

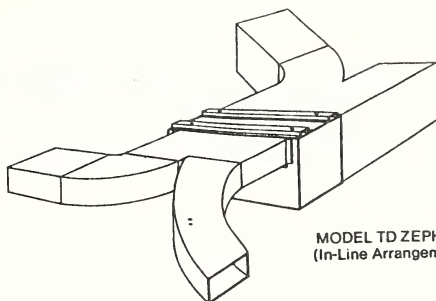
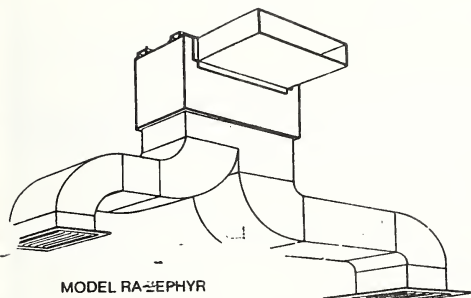
SNAP OFF: Light off immediately. Zephyr runs from 4 to 15 minutes* to clear the air after the room is left vacant.

*The longer the room is used, the longer the Zephyr runs after the switch is OFF. The AIRMINDER can also be used with a separate light switch or no light at all to provide the same features as described above. Penn also makes available a COMBINATION LEK-TROL, AIRMINDER (2 gang box required) so that both, variable speed and time delay features, are combined. Wiring diagrams are available for combination switch installations and for multi switch location installations.



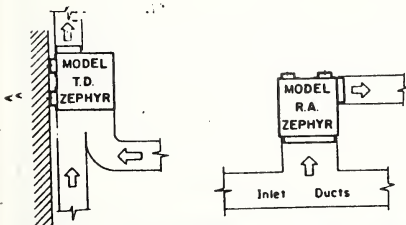
CAST IRON OR STAINLESS STEEL

UTILITY SETS
DON'T BELONG
ABOVE CEILINGS OR IN
REMOTE LOCATIONS IN
TODAY'S CONFERENCE
ROOMS



FEATURES

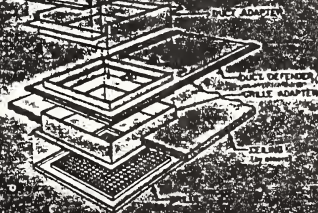
- Performance range to 3000 CFM. Adjustable direct drive thru matching Lek-Trol solid state controller; Permits precise balancing and easy change in volume.
- Quiet design—insulates casing and cuts ear pollution. Employs resiliently mounted, continuous duty motors revolving large and efficient wheels at low speeds.
- Trim, compact low profile units are easy to install above dropped ceilings and in confined spaces.
- Versatile direction of discharge provides equal efficiency from either straight-thru or right-angle outlet.
- Access panel removes easily and permits full entry into unit.



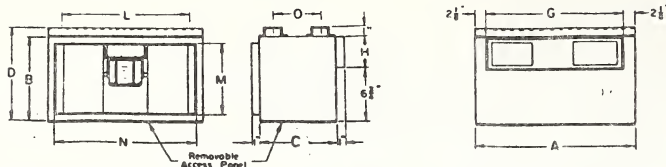
Typical Installations—As a standard, units are shipped for right angle discharge (Model RA). When Top Discharge mode (Model TD) is required, access panel and duct flange are easily removable for remounting in the field to switch to Top Discharge or In-Line Arrangement.

ZEPHYR with Duct Defender For Fire Rated Ceiling—Floor Assemblies

Fire rated ceiling-floor systems need not lose their U.L. rating. The ZEPHYR ceiling fan line is available with Duct Defender radiation ceiling damper, a U.L. labeled product. The Duct Defender ceiling damper is supplied for mounting between the ZEPHYR ceiling fan and its grille and provides three (3) hour fire protection as listed in U.L. Fire Resistant Index. The complete assembly is shown here. Note that the duct and grille adaptors are furnished along with the fan, damper and grille for a guaranteed fit. Specify the Duct Defender-ZEPHYR combination when fire rated ceiling-floors are pierced.



PENN ZEPHYR CABINET FAN



MODEL	A	B	C	D	G	H	L	M	N	O	SHIP. WT. (lbs.)	WHEEL SIZE DIA.	WHEEL SIZE C.R.F.	INLET AREA (sq. ft.)	OUTLET AREA (sq. ft.)
Z14	38	14½	14½	15½	33½	7½	30½	12½	36	7½	85	8 in.	2.09 ft.	3.125	1.816
Z15	45½	16½	16½	17½	41½	9½	34½	14½	43½	10	95	9 in.	2.36 ft.	4.38	2.793

All dimensions are in inches.

Housing—Cabinet Fan casings are lined with sound absorbing acoustical insulation securely fastened to the steel walls of the cabinet. Cabinet exterior has a double painted finish.

Direct Drive—Trouble free design operates smoothly and quietly with permanently lubricated, continuously duty PSC, thermal protected, ball bearing motors. Backdraft dampers are available as an optional accessory for use with Zephyr Cabinet Fans. These are installed at the factory in the exhaust-side duct flange. Zephyr Cabinet Fans are available with inlet guards or thin-line protective louvers when inlet openings are exposed.

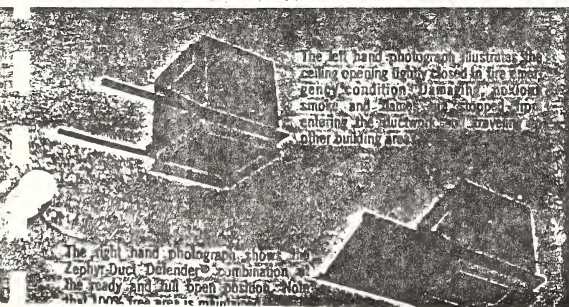
PERFORMANCE TABLE

MODEL Z14			15 1/2 HP			12 1/2 HP																					
FAN CAPACITY — CUBIC FEET PER MINUTE																											
RPM	.10" S.P.			.125" S.P.			.25" S.P.			.375" S.P.			.50" S.P.			.625" S.P.			.75" S.P.			.875" S.P.			1.0" S.P.		
	CFM	SONES	BHP	CFM	SONES	BHP	CFM	SONES	BHP	CFM	SONES	BHP	CFM	SONES	BHP	CFM	SONES	BHP	CFM	SONES	BHP	CFM	SONES	BHP	CFM	SONES	BHP
1100	1650	7.1	.37	1635	7.0	.362	1490	6.8	.325	1335	6.5	.268	1165	6.2	.201	950	5.9	.091	560	5.6	.067						
1080	1535	7.0	.349	1505	6.9	.341	1330	6.7	.305	1115	6.4	.245	860	6.1	.176												
1030	1450	6.7	.3	1415	6.6	.294	1230	6.4	.256	1005	6.1	.196	710	5.8	.137												
980	1370	6.3	.256	1330	6.2	.25	1130	6.0	.206	875	5.7	.153															
880	1200	5.4	.181	1160	5.3	.175	910	5.2	.132	565	4.9	.077															
780	1025	4.7	.121	975	4.6	.116	670	4.5	.073																		

MODEL Z15			230/1/30			18 HP																					
FAN CAPACITY — CUBIC FEET PER MINUTE																											
RPM	.10" S.P.			.125" S.P.			.25" S.P.			.375" S.P.			.50" S.P.			.625" S.P.			.75" S.P.			.875" S.			1.0" S.P.		
	CFM	SONES	BHP	CFM	SONES	BHP	CFM	SONES	BHP	CFM	SONES	BHP	CFM	SONES	BHP	CFM	SONES	BHP	CFM	SONES	BHP	CFM	SONES	BHP	CFM	SONES	BHP
1100	2960	9.2	.907	2930	9.1	.898	2800	8.8	.825	2650	8.4	.75	2480	8.0	.664	2270	7.7	.556	2000	7.3	.422	1670	7.0	.35	600	6.7	.117
1080	2860	9.0	.857	2830	8.9	.848	2660	8.6	.776	2460	8.2	.701	2210	7.8	.617	1880	7.5	.503	1450	7.1	.384						
1030	2720	8.6	.741	2690	8.5	.728	2500	8.2	.661	2280	7.8	.589	2000	7.4	.503	1600	7.1	.377									
980	2570	8.1	.635	2540	8.0	.621	2340	7.7	.555	2090	7.3	.484	1760	6.9	.389	1280	6.6	.256									
880	2280	6.9	.45	2240	6.8	.44	2000	6.6	.379	1680	6.3	.307	1150	5.9	.202												
780	1980	6.1	.305	1930	6.0	.294	1630	5.8	.237	1130	5.5	.152															

Top RPM shown is nominal and the performance is based on actual speed of test. Other speeds listed are obtainable by using matching Lek-Trol speed controller. Lek-Trol Model LT40 for cabinet fan Model Z14, and Lek-Trol Model LT35 for cabinet fan model Z15. Sone ratings in accordance with AMCA Bulletin 300-67. The AMCA Certified Ratings Seal applies to air capacities only.

See page 8 for larger capacity In-Line fans.



SUGGESTED SPECIFICATIONS

All ceiling fans, indicated on the plans and schedule shall be direct driven ZEPHYR Model (26, 28, Z10, Z12, Z14, and Z15) by Penn Ventilator Company, Inc., Red Lion and Gentry Roads, Philadelphia, Penna. 19115. Fans shall have acoustically insulated housings and shall have maximum sound level rating as noted. Air deliveries and Sone levels shall be as indicated on the plans and all fans shall bear the AMCA Certified Ratings Seal for air capacities only and the U.L. label. Manufacturer shall submit vibration amplitudes and magnetic motor hum levels in decibels. Integral backdraft damper shall be chatterproof. Fans shall have true centrifugal wheel (or wheels) with inlet perpendicular to, or remote from, inlet grille. Grille shall be of aerodynamic design of white eggcrate shape and provide 85% free open area. Terminal box shall be provided with cord, plug and receptacle inside the housing. Entire fan, motor and wheel assembly shall be removable without disturbing the housing. Motor speeds shall not exceed 1100 RPM and all fan motors shall be suitably grounded and mounted on rubber-in-shear vibration isolators. When fire rated ceiling-floor systems are pierced, provide factory mounted Duct Defender U.L. labeled ceiling dampers in combination with fans where indicated on the drawings.

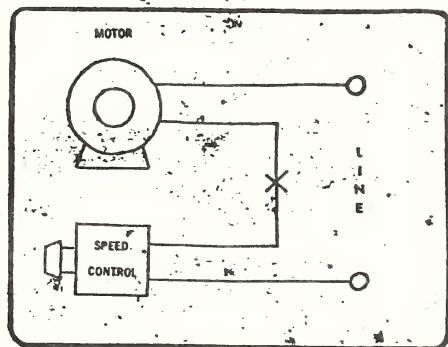
INSTRUCTIONS FOR INSTALLING WALL-MOUNT SPEED CONTROL

1. APPLICATION

- Motor Type — Shaded-Pole, P.S.C., and Universal.
- Required Load — Fans, Blowers, and speed dependent loads.

2. WIRING

Connect control in series with motor and line voltage — never connect control across line.



3. MOUNTING

- Use 2" deep standard Gem Box.
- Secure control with outer bracket tabs.

4. MINIMUM SPEED ADJUSTMENT

This control was designed to operate on motors used in diversified applications. A minimum speed adjustment is provided to allow independent control of the minimum speed setting.

- Motor must be in actual operating conditions to achieve proper speed adjustment. (Motor will not slow down unless proper load is applied.)
- Turn main control knob clockwise to lowest speed position.

- Locate and adjust minimum speed setting on front plate with screw driver (rotate clockwise to decrease minimum speed; counter-clockwise to increase minimum speed) so that motor runs with sufficient torque to prevent stalling.
- Motor will now operate from this preset minimum speed to full speed.

5. FINAL MOUNTING

- Install front dial plate.
- Turn main control counter-clockwise until switch snaps off.
- Push on knob so that pointer is in off position.



RHO SIGMA

11922 VALERIO ST., NO. HOLLYWOOD, CA. 91605

(213) 982-6800

February 8, 1978

Mr. Bob Corbett
P.O. Box 3706
Butte, MONTANA 59701

Dear Bob:

As per our telecon today, please find the Applications Manual and other pertinent literature.

I have enclosed on a separate sheet information on the RS12 VT and a 5" X 7" glossy picture.

Also enclosed is an installation diagram on the RS500 single output for added information about this solid state control. Keep in mind the need for a contactor to up the load capabilities.

It was good to hear from you and I hope Rho Sigma will fit the bill!

Sincerely,

John Derzay
Marketing Department

JD:re
Enclosures

RHO SIGMA

RS 12 VT

Adjustable ΔT ON 4°F to 20°F

ΔT OFF $\Delta 3^\circ F$

Input: 115 VAC 50 - 60 HZ

Output: SPDT relay rated @ 10 amps.

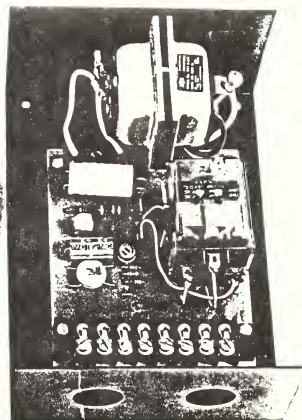
1/3 H.P. @ 120 VAC 50-60 HZ

PCB mounted in 5" X 7" X 3" steel enclosure.

Suggested List: \$116.78

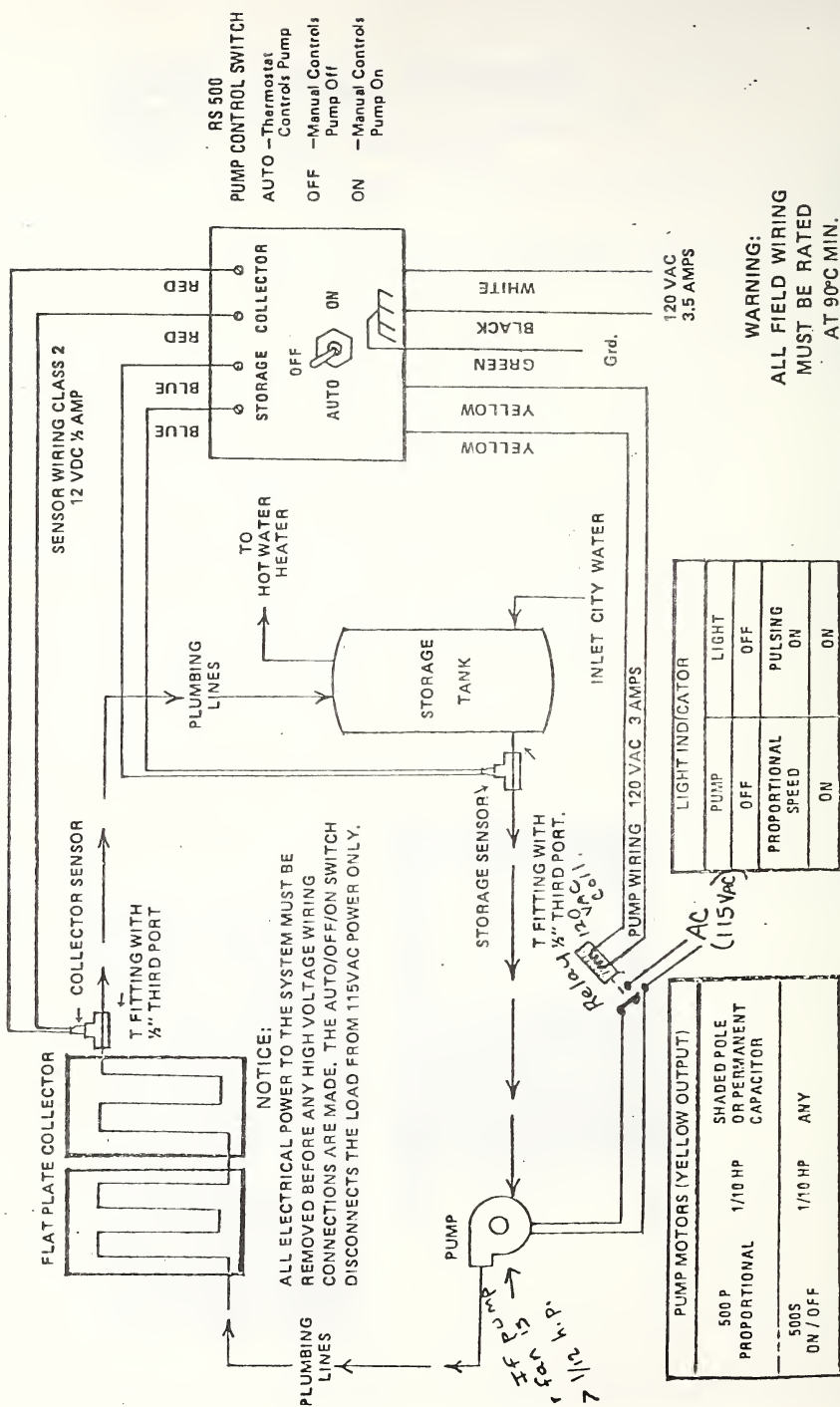
Current Trade: \$ 73.69

Delivery : 2 weeks ARO.



DIFFERENTIAL THERMOSTAT INSTALLATION DRAWING

RS 500-1 SINGLE OUTPUT (Rev. A)



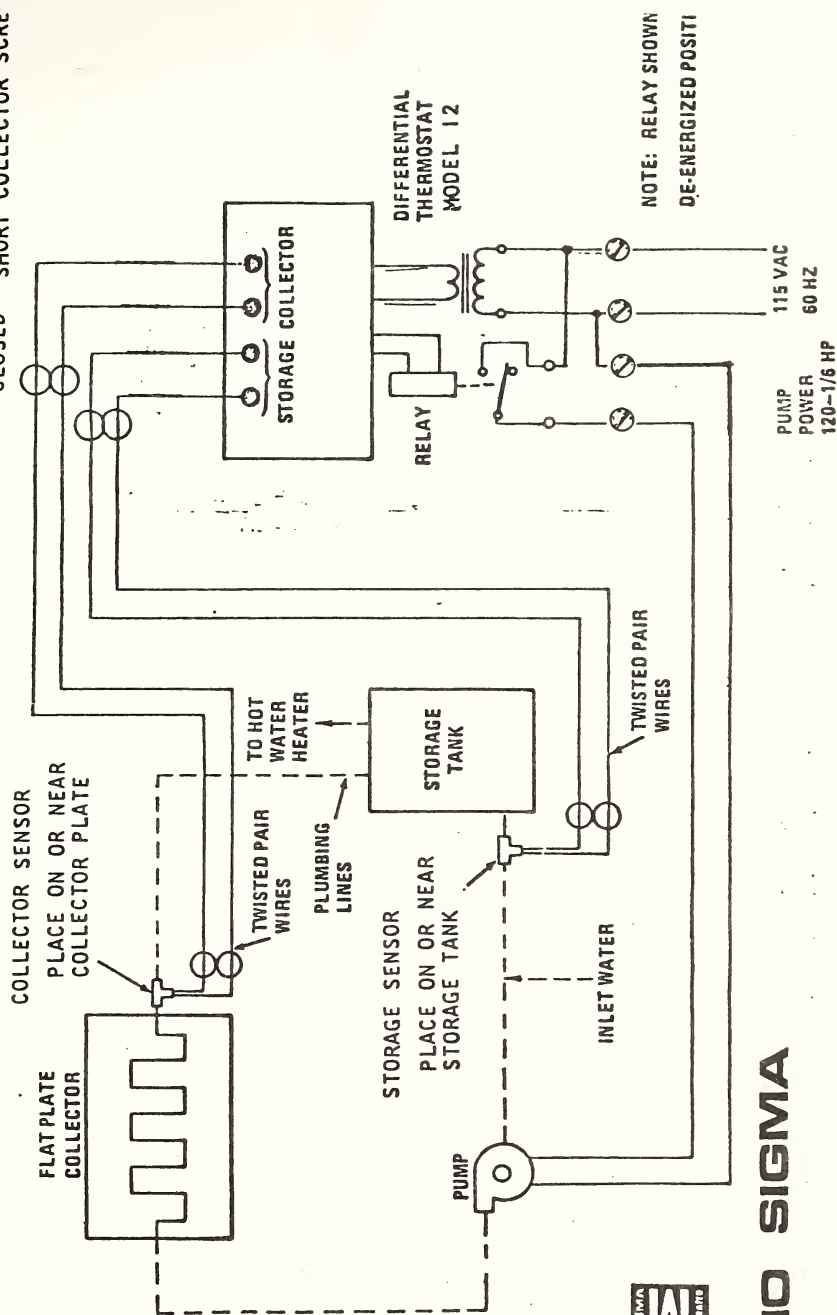
WARNING:
ALL FIELD WIRING
MUST BE RATED
AT 90°C MIN.

Relax in de-energized

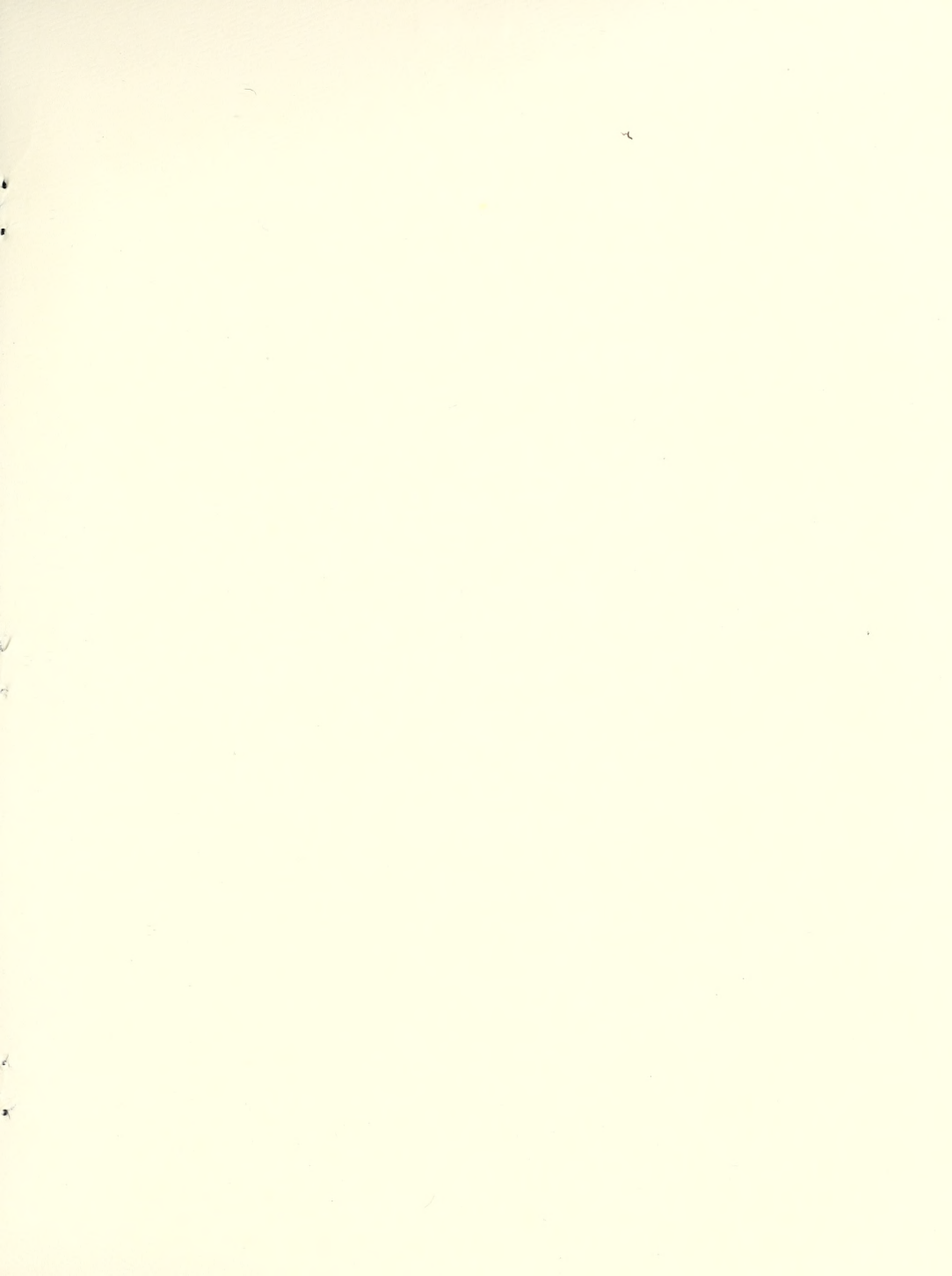
RHO SIGMA DIFFERENTIAL THERMOSTAT INSTALLATION DRAWING

RELAY TEST

OPEN - SHORT STORAGE SCREWS
CLOSED - SHORT COLLECTOR SCREW



RHO SIGMA



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